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EVALUATION OF PROPOSED C-141 ELECTRONIC DISPALY FORMATS AND MENUS

VOL 1 - PART-TASK SIMULATION

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NOTICE

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The Warner-Robins Air Logistics Center has initiated a program to replace the current cockpit flight instruments with a new Control / Display System (CDS). The new CDS includes (1) Liquid Crystal Display (LCD) units for the presentation of electronic Primary Flight Display Formats and (2) the addition of a Display Avionics Management Unit (DAMU) for controlling primary flight and navigation functions. The Wright Laboratory Cockpit Integration Division has supported this upgrade program through a two-phase pilot-in-the-loop simulation evaluation effort. In Phase I, the PFD format and the DAMU were evaluated in part-task simulations. In Phase II, a full mission evaluation was conducted to verify that the integrated system would support C-141 mission requirements. This report describes the methods and results of the part-task simulation. Four primary flight display formats (CDS Attitude, CDS Climb-Dive, C-141, and the T-1) were compared through a series of instrument flying tasks. Performance with the CDS displays was "as good as or better" than the others. However, numerous deficiencies were identified through questionnaires and pilot comments. Two DAMU menu designs (proposed CDS design, and a WL/FIP alternative design) were compared using a scripted role-playing task. Overall, performance and subjective results showed that both DAMU designs would be suitable for use in the C-141 with minor modifications. Specific recommendations are provided for both the CDS PFD format and DAMU design.

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GLOSSARY

ADI	Attitude Director Indicator
AFB	Air Force Base
AFCS	Automatic Flight Control System
AFM	Air Force Manual
ANOVA	Analysis of Variance
AP	Autopilot
ASC	Aeronautical System Center
ATC	Air Traffic Control
AWFCS	All Weather Flight Control System
AWG	Autopilot Working Group
BDHI	Bearing Distance Heading Indicator
BIT	Built-in Test
CARP	Computed Airdrop Release Point
CCT	Combat Control Team
CDM	Climb-Dive Marker
CDS	Control Display Subsystem
CDU	Control Display Unit
CONOP	Concept of Operations
CRT	Cathode Ray Tube
CSIL	Crew Station Integration Laboratory
DAMU	Display Avionics Management Unit
DICU	Display Interface Control Unit
DME	Distance Measuring Equipment
FCR	Flight Command Repeater
FD	Flight Director
FPM	Flight Path Marker
FSAS	Fuel Savings Advisory System
FSDG	Flight Symbology Development Group
HSI	Horizontal Situation Indicator
IFR	Instrument Flight Rule

GLOSSARY (CONT'D)

ILS	Instrument Landing System
INS	Inertial Navigation System
JCO	Joint Cockpit Office
LCD	Liquid Crystal Display
LSK	Line Select Keys
MANOVA	Multivariate Analysis of Variance
MFD	Multi-Function Display
NAVAIDS	Navigational Aids
NDB	Non-Directional Beam
NSP	Nav Select Panel
NVGs	Night Vision Goggles
PFD	Primary Flight Display
PICT	Precision Instrument Control Task
PICU	Pilot's INS Control Unit
RMS	Root Mean Square
RRI	Relative Range Indicator
RSP	Reference Set Panel
SFD	Secondary Flight Display
SKE	Station Keeping Equipment
SOLL	Special Operations Low Level
SWAT	Subjective Workload Assessment Technique
SWORD	Subjective Workload Dominance
TACAN	Tactical Air Navigation
TOT	Time Over Target
TRAC	Transport Aircraft Cockpit
UAR	Unusual Attitude Recovery
VDI	Vertical Deviation Indicator
VHF	Very High Frequency
VOR	VHF Omni Range
VVI	Vertical Velocity Indicator

GLOSSARY (CONT'D)

WL/FIGP	Wright Laboratory Cockpit Integration Division
WR-ALC	Warner Robins Air Logistics Center
ZM	Zone Marker

LIST OF FIGURES

INTRODUCTION

Warner-Robins Air Logistics Center (WR-ALC) has initiated a program to incorporate the All Weather Flight Control System (AWFCS) into the C-141 cockpit. As part of the upgrade, current cockpit flight instruments will be replaced with a new Control/Display Subsystem (CDS) consisting of four Liquid Crystal Display Units, two Display Avionics Management Unit and a variety of modified control panels. Figure 1 illustrates a comparison of current and the upgrade cockpits.

In support of this cockpit upgrade effort, the Wright Laboratory Cockpit Integration Division conducted a pilot-in-the-loop simulation program to develop and evaluate the display format and menu interfaces being implemented on the CDS hardware. The Wright Laboratory effort focused on the three main functional components of the CDS: the Primary Flight Display, the Secondary Flight Display, and the Display Avionics Management Unit (DAMU). Figure 1 shows the placement of the PFD, SFD and DAMU in the C-141 cockpit.

The ***Primary Flight Display (PFD)*** format will provide all instrument flying information, including ADI, HSI, Airspeed Scale, Altitude Scale, Heading, Bank, etc. The PFDs will replace the C-141's electro-mechanical ADI, HSI, airspeed and barometric altitude indicators.

The ***Secondary Flight Display (SFD)*** format will provide supplementary flight and route information. There are 3 possible SFD formats available for presentation: HSI, MAP and SKE.

The ***Display Avionics Management Unit (DAMU)*** menu interface will control the PFD format, SFD formats, and various navigation functions. The DAMU will replace the C-141's Nav Select Panel.

The simulation program was conducted in two phases. In the first phase, the PFD and DAMU were individually evaluated in a part-task context to compare alternative design configurations and to evaluate specific format elements. Design changes were made based on the part-task results. In the second phase, the revised CDS components (PFD, SFD and DAMU), were evaluated as an integrated system in a full mission simulation. The method and results of the full mission evaluation can be found in Toms, Cone, Gier, Boucek, & Brown and Patzek (in press).

The purpose of this report is to document the method and results of the part-task evaluation of the PFD format and DAMU menu interface. After a brief summary of the PFD and DAMU analysis and design effort, the methods, results and conclusions for the PFD evaluation will be discussed. The method, results and conclusions of the DAMU evaluation will follow. Both the PFD and DAMU part-task evaluations will then be summarized in a general conclusions section.

Analysis and Design Effort

The tested designs were developed through a cooperative effort between Wright Laboratory's Cockpit Integration Division

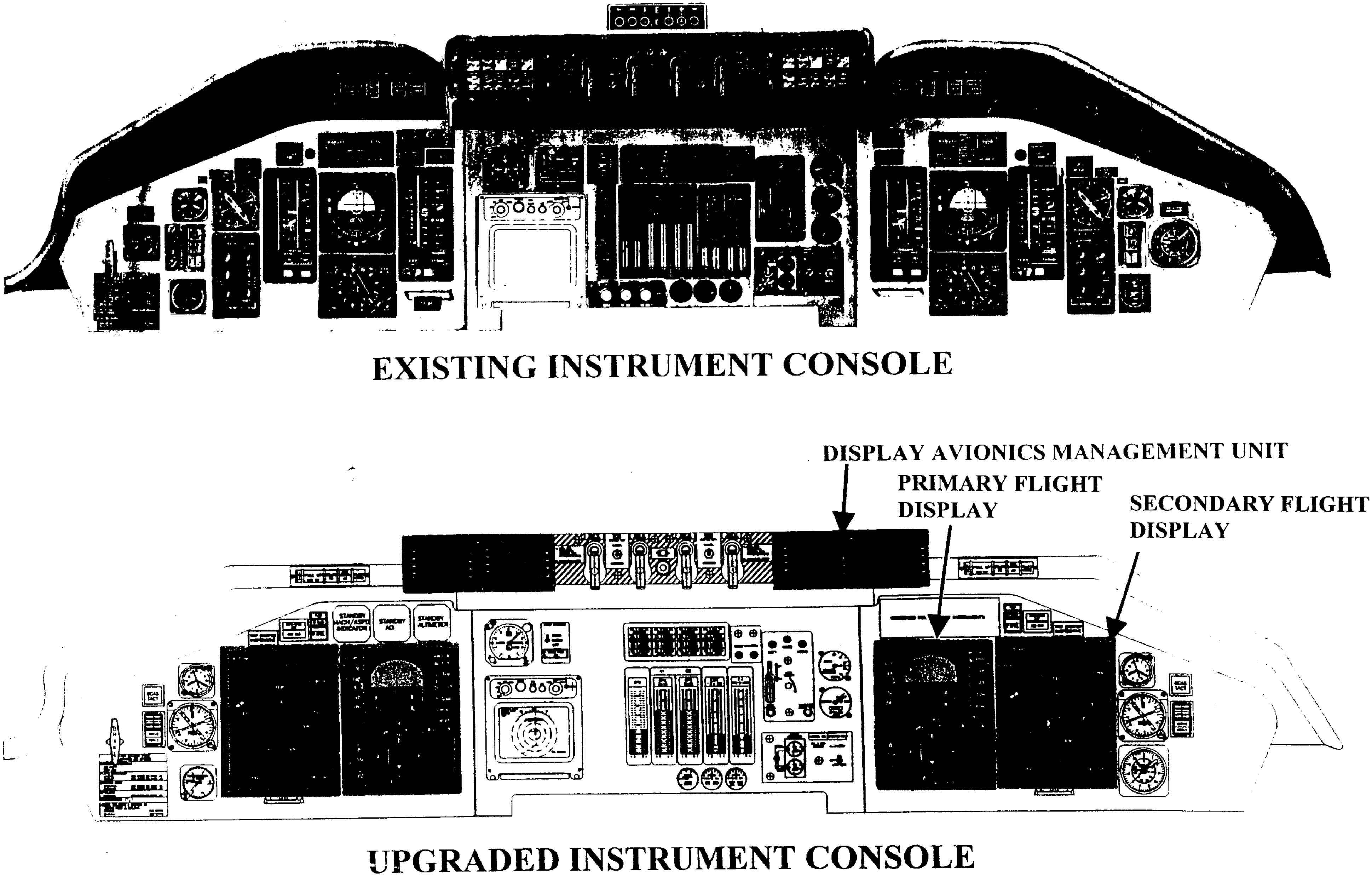

Figure 1. Current abd Planned Upgrade C-141 Cockpits.

(WL/FIGP), the Joint Cockpit Office (JCO), and the C-141 Autopilot Working Group (AWG). The C-141 CDS Concept of Operation (CONOP), Rev A served as a baseline design.

Two design goals drove the design process. The first goal was to insure that the design provided at least the same capability as the current C-141 configuration. A second design goal applied only to the PFD. This goal required the PFD to be in compliance with the future military standard for electronic head-down primary flight display formats which is being developed by JCO's Flight Symbology Development Group (FSDG).

To support the design effort, a variety of analysis activities were conducted. First, a mission and functional analysis was performed to identify relevant C-141 missions and functions that needed to be supported by the design, and to aid in the definition of simulation task requirements. This was followed by a control/display analysis to determine if all current C-141 control/display functions were provided by the new design. Technical assessments were then conducted to evaluate operational and human factors issues of the proposed designs. The results of these analyses were then fed back into the design effort, where identified design deficiencies were refined through an iterative process.

The Wright Laboratory analysis and design effort also involved defining detailed symbol designs, dimensions, mechanizations, and interactions for the various elements of the PFD, SFD and DAMU formats. These definitions are documented in a functional specification for the C-141 PFD symbology which is included as an appendix of Volume II: Full Mission Simulation report. The functional specification is a baseline for development of a military standard for a head-down electronic PFD format and the basis for the development of symbology software specifications.

PRIMARY FLIGHT DISPLAY EVALUATION

Objectives

The part-task PFD evaluation effort served two objectives. The first was to assess the suitability of the proposed PFD designs for use as a primary flight reference in the C-141. The second was to collect performance data and subjective ratings in support of the FSDG effort to develop a head down primary flight display standard for large military aircraft. To accomplish these objectives, pilot performance and subjective ratings were compared across the following four formats.

(1). CDS Attitude Format (Figure 2). The CDS Attitude Mode is one of two PFD modes being considered for incorporation into the C-141. It provides all required primary flight information on a 6 x 8 inch Liquid Crystal Display. A graphical ADI is presented on the top half of the display area and provides pitch, climb dive, and bank information. Command guidance information (pitch and bank steering bars) are referenced to the pitch symbol and are shown when appropriate navigation or Station Keeping Equipment (SKE) modes are selected. A Horizontal Situation Indicator with a full compass rose is displayed below the ADI, and provides navigational information including heading, ground track, course deviation, course selection, and bearing to two selectable navigation sources. Selected navigation sources and Distance Measuring Equipment (DME) are indicated

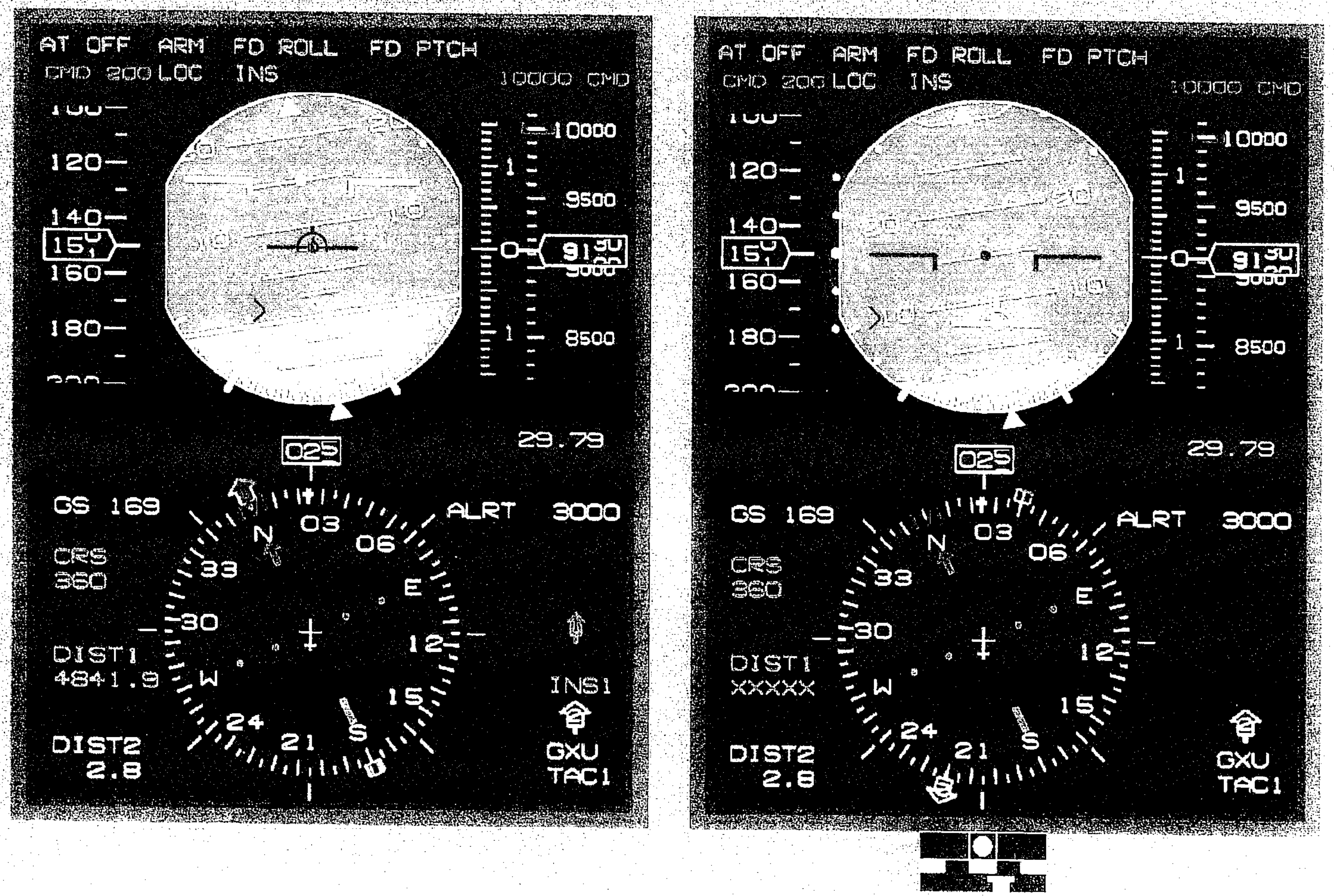

Figure 2. CDS Attitude and Climb-Dive PFD Format.

beside the HSI. Airspeed and altitude are presented in a vertical moving tape format to the left and right of the ADI, respectively. Both include a digital readout and command markers. The VVI is shown in a vertical "thermometer" format and is located between the altitude scale and ADI. Various flight mode and alerting annunciations are presented along the top of the display. This format was distinguished from the CDS Climb-Dive Format in that the pitch ladder was referenced to a fixed miniature aircraft symbol rather than a climb-dive symbol.

(2). CDS Climb-Dive Format (Figure 2). The CDS Climb-Dive Format is identical to the CDS Attitude Format, with the exception that the pitch scale is referenced to the Climb-Dive Marker (CDM) rather than a miniature aircraft symbol. As a result, the CDM is used as the primary aircraft control symbol. This format was included because it was recommended as an optional display mode in the C-141, and to explore its potential utility as a PFD format.

(3). C-141 electromechanical suite (Figure 3). This was a graphical depiction of the current electromechanical flight instruments (as described in T.O. 1C141B-1, (1992) and was included to satisfy the interests of the C-141 community, and for comparison with the CDS formats. The goal was to demonstrate that pilot performance with the CDS Formats was "at least as good as" that for the C-141. This criteria was established to ensure that capability was not being lost as a result of the incorporation of the CDS format.

(4). T-1 electronic display configuration (McDonnell Douglas Training System, 1993). This configuration (Figure 4) was included to support the head-down standard development effort. It was intended to be used as a performance reference since it has been used extensively in commercial aviation, is Federal Aviation Administration (FAA) certified, and is an electronic format currently being used in a military transport trainer aircraft.

Method

To accomplish the objectives of the PFD evaluation, pilot performance data were collected on a series of instrument flying tasks: Unusual Attitude Recoveries (UAR) were used to evaluate the ability of the proposed display to provide an immediately discernible attitude reference for aiding a quick recovery control input decision. Precision Instrument Control Tasks (PICT), and Instrument Landing System (ILS) approaches provided an assessment of the proposed PFD for basic instrument flying. Subjective questionnaire responses and debriefing interviews were used to diagnose design deficiencies associated with specific display elements. This approach was designed to be similar to the methods used for the standard Head Up Display (HUD) symbology validation effort (Hughes, Hassoun, and Barnaba, 1993).

Subjects

A total of 18 pilots participated in the evaluation. Thirteen of the test subjects were active duty or reserve C-141 pilots with the following distribution of experience levels: 2 copilots, 3 first pilots, 3 aircraft commanders, and 5 instructor or evaluator pilots. C-141 flight hours for these pilots ranged from 300 to 5500, with an average of 1866 hours.

Five pilots were selected to represent a variety of military aircraft experience, and

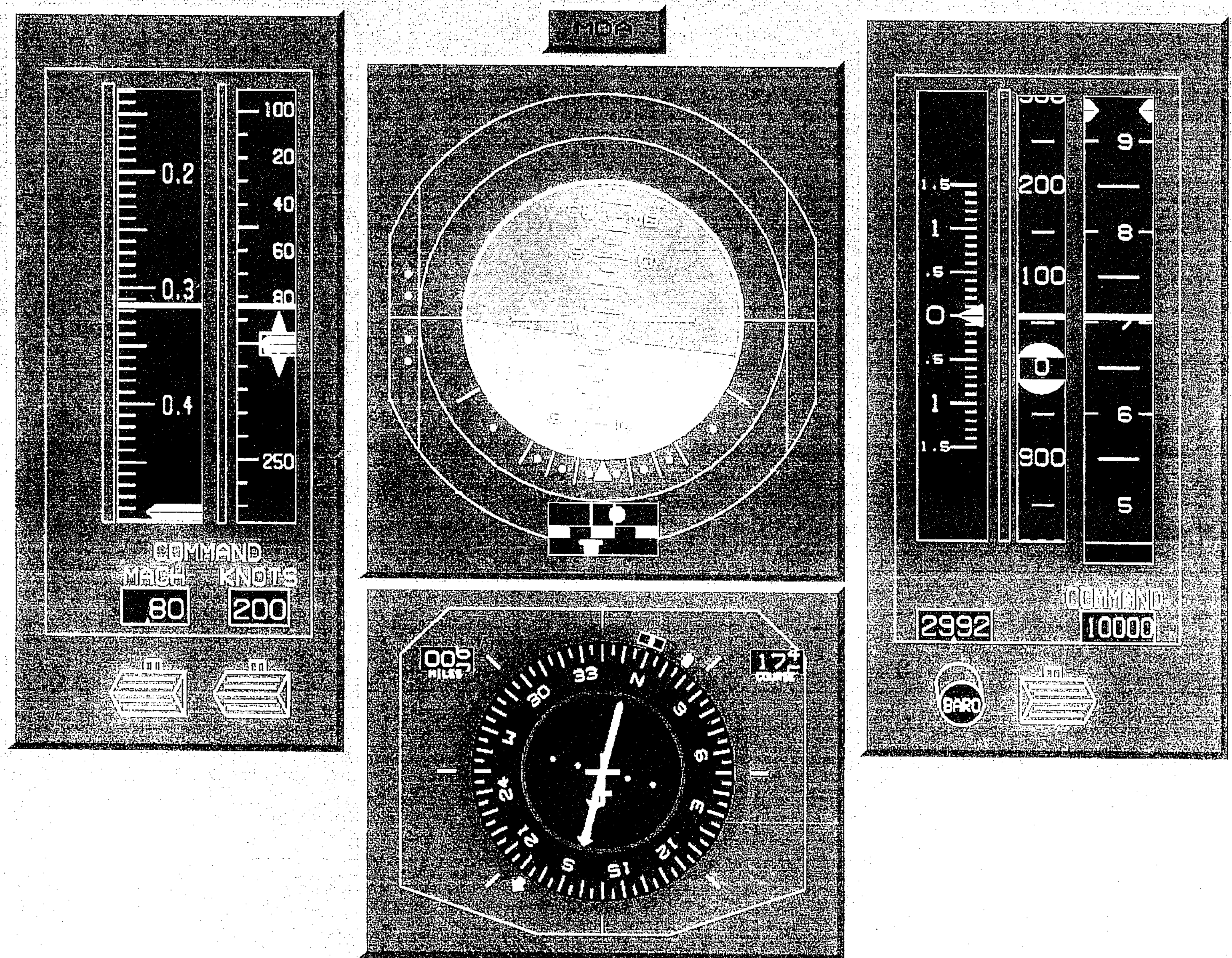

Figure 3. C-141 Analog PFD Format.

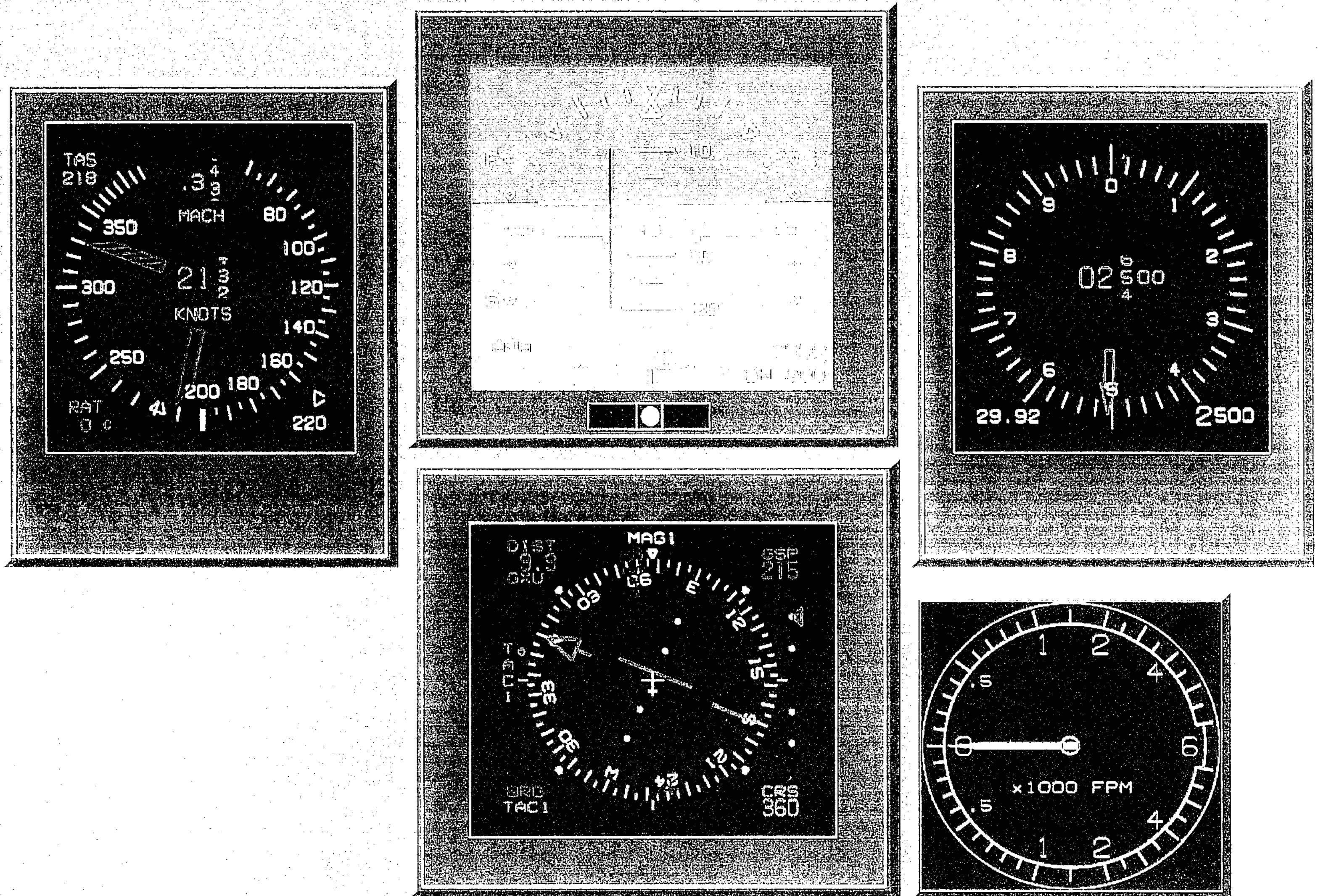

Figure 4. T-1 Electronic PFD Format.

were primarily included to support the head-down specification development effort. This group was comprised of 3 KC-135 pilots (2 aircraft commanders and 1 evaluator pilot) whose KC-135 flight hours ranged between 1300 and 2300, with an average of 1700, and two flight test center pilots with experience in a wide range of transport aircraft, including the C-141.

Apparatus

Transport Aircraft Cockpit Simulator

The evaluation was conducted in the TRansport Aircraft Cockpit (TRAC) Simulator located in the Aeronautical Systems Center (ASC) WL/FIGP Crew Station Integration Laboratory (CSIL). The simulator was configured to provide a similar cockpit geometry to the C-141 aircraft. The cockpit shell contained three crew member stations: pilot, copilot and flight engineer. For purposes of this evaluation, only the pilot's station was configured for flying tasks. The copilot's station was not used for testing. The test engineer controlled the simulator and experiment from a computer terminal mounted at the flight engineer station.

Three 21 inch Mitsubishi Cathode Ray Tube (CRT) color display monitors (1280 x 1024 pixel resolution) that were mounted across the front of the cockpit. One each was mounted in front of the pilot and copilot's seated positions, and the third was placed in the center of the main instrument panel. Only the pilot's and center monitors were used for testing. The PFD formats were shown on the pilot's monitor; graphically drawn engine instruments, Bearing Distance Heading Indicator (BDHI), C-141 radar altimeter, trim tab position indicators, and flap and spoiler indicators were displayed on the center CRT monitor. An additional 16 inch direct view (CRT) was used to display an out-the-window visual scene to the pilots position only. This showed a zero visibility condition above 200 feet altitude. A generic yoke, throttle, landing gear handle, and flaps handle were provided for flight control. A Reference Set Panel (RSP), located on the center console between the pilot and copilot positions, was provided for control of commanded airspeed, commanded altitude, heading marker and course selection. A fully operational DAMU was mounted at the top of the glareshield, as proposed for the C-141 upgrade; however, no DAMU inputs were required of the subject pilots during the PFD evaluation. The cockpit also contained various operational and mocked-up control panels and displays, but these were not used during the evaluation. The simulator was driven by a KC-135 aerodynamic model. The displays and aeromodel were driven by four Silicon Graphics IRIS Computers. A photograph of the cockpit is provided as Figure 5.

Experimenter's Console

The experimenter's console provided the capability for the test engineer to select all relevant experimental parameters, including display format, subject number, task type, and trial number. The console also provided feedback on these selections to the test engineer, and the status of various parameters throughout the study, such as PFD blanking, winds, and data collection activity. The console was also used to initiate and terminate the practice, test trials, and demonstrations.

Display Formats

Four primary flight formats were compared in the evaluation: (1) CONOP Attitude Format (Figure 2), (2) CDS Climb-Dive

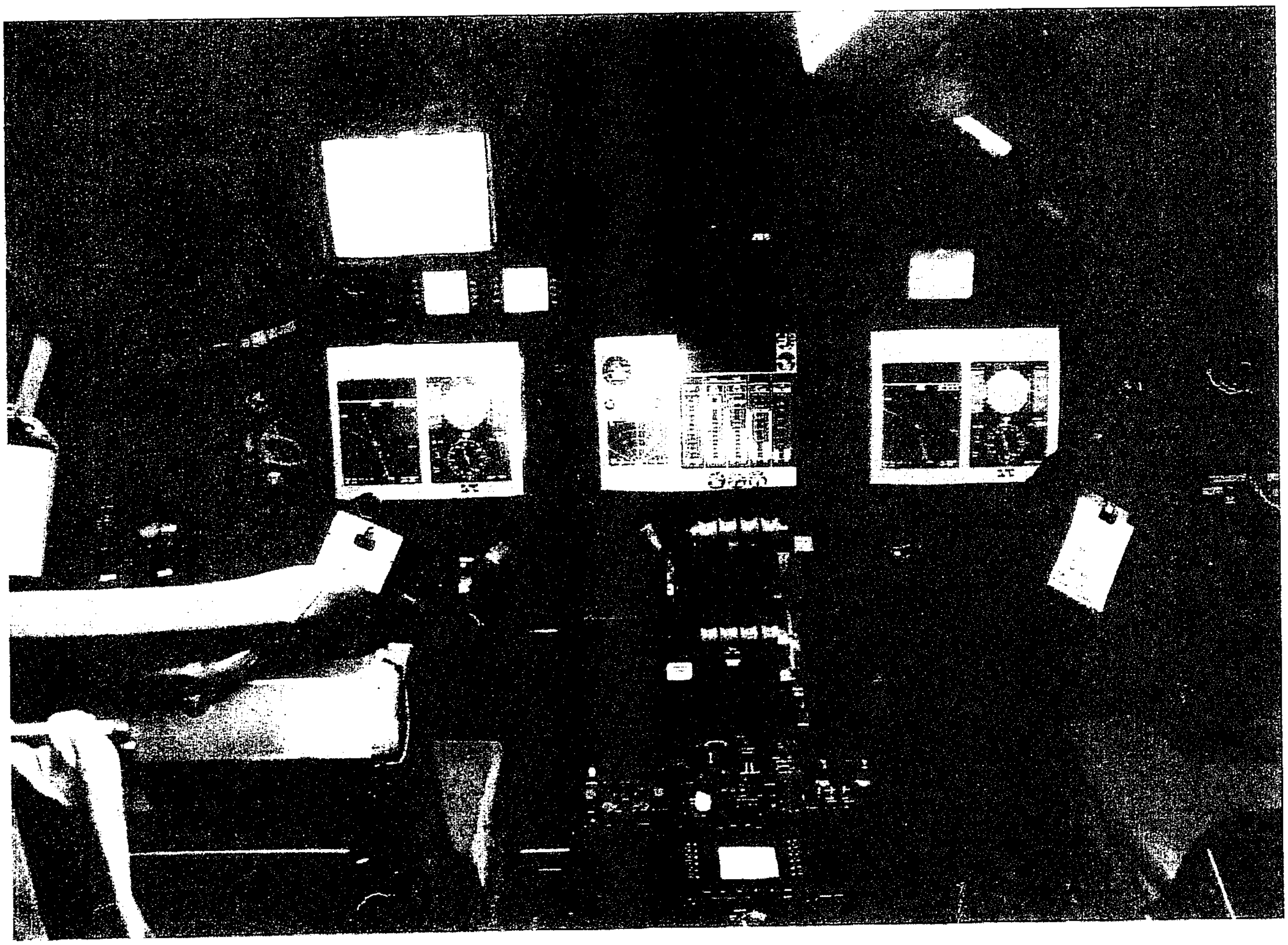

Figure 5. Transport Aircraft Cockpit Simulator.

Format (Figure 2), (3) C-141 analog flight instrument suite (Figures 3 and 4) the T-1 electronic flight instrument suite (Figure 4). These formats were reproduced graphically on the large-screen CRT displays. Detailed drawings and descriptions of the four formats are provided in Appendix A.

Procedure

Two pilots per week participated in the evaluation. Each was given an initial training session followed by four data collection sessions over the course of the week. The subjects also participated in the DAMU part-task evaluation during their stay.

Training Sessions

Each pilot was given a 2 hour training briefing that provided program background, detailed description of the four PFD formats and procedures for the flying tasks. Then, each pilot received an additional two hours of hands-on cockpit training during which each of the tasks were flown. Pilots flew a series of basic maneuvers to become familiar with the simulator characteristics, 20 UARs (5 with each PFD format), each of the PICT tasks, and two ILS approaches. During the hands-on training the pilot was provided sufficient opportunity to become familiar with the operation of each PFD format.

Evaluation Tasks

Each pilot evaluated each PFD format by flying a series of instrument flying tasks: (1) UARs, (2) PICTs, and (3) ILS Approaches. Each pilot was also given the opportunity to fly unstructured demonstrations for purposes of subjective evaluation. Each of the instrument flying tasks are described below.

Unusual Attitude Recoveries

UARs were accomplished by each pilot to assess the ability of the proposed PFD to provide an immediately discernible attitude indication and to provide sufficient information for quick and accurate unusual attitude recovery. A variety of extreme pitch and roll attitude conditions were presented to the pilot. For each UAR, the cockpit display was initially blank and the pilot was instructed to set the yoke to the center position, set the throttles to the 30 degree position, and wait for the engines' parameters to stabilize. When ready, the pilot started the trial via a pushbutton switch located on the throttle, which initialized the simulator to a predefined unusual attitude. After a short, variable delay (1-3 seconds), the PFD appeared and the pilot was instructed to recover to within 5 degrees of straight and level flight as quickly and as accurately as possible, using standard C-141 Air Force recovery procedures. The display once again blanked after the pilot maintained less than +/- 5 degrees of climb-dive and bank for at least 5 seconds. Finally, the next trial was begun. All trials started with the simulator at an altitude of 10,000 feet. The visual scene displayed zero visibility conditions, with no discernible horizon.

Pilots were instructed to use recovery procedures described in AFM 51-37 (Department of the Air Force, 1986). For a climb condition, the procedure was to set throttles to full, roll to the nearest 30 degree bank condition (left or right) and allow the nose to drop to the horizon. For a dive condition, the procedure was to set throttles to idle, and then roll and pull to straight and level flight.

Precision Instrument Control Tasks

PICTs were used to evaluate the adequacy of the proposed PFD formats for basic flight control. In these tasks, the pilot was required to maintain precise control over various flight parameters. Each of the following tasks was flown with each PFD format:

(1) Vertical S-A. 1,000 feet per minute (fpm) descent from 10,000 to 9,000 Mean Sea Level (MSL), 1,000 fpm climb to 10000 MSL, maintaining either 180 or 240 knots and heading 360 degrees: repeated 2 times.

(2) Vertical S-D. 1,000 fpm descent from 10,000 to 9,000 MSL while maintaining a 30 degree bank, reverse bank direction, perform a 1,000 fpm climb to 10,000 MSL while maintaining a 30 degree bank in the opposite direction, repeated 2 times. Either 180 or 240 knots airspeed was maintained throughout the maneuver.

(3) Steep turns. 45 degree level turns while maintaining 10,000 feet MSL and either 180 or 240 knots. Two 360 degree turns are performed.

(4) Level flight. Maintain 10,000 MSL, heading 360 degrees, and either 180 or 240 knots for one minute.

After describing the maneuver, the experimenter released the simulator at 10,000 feet MSL and at the appropriate airspeed. After stabilizing the simulator at the initial parameters, the pilot was instructed to depress the throttle switch (to insert an event marker in the data file) and begin the maneuver. After completion of the maneuver, the experimenter froze the simulator and provided instructions for the next task. No external visual scene was provided for any of the PICT tasks.

Instrument Landing System Approach Task

Each pilot performed 3 ILS approaches to McGuire Air Force Base (AFB) for each PFD format. The simulator was released on the 14 Distance Measuring Equipment (DME) arc, at 3,000 feet and 200 knots. The pilot was required to maintain the arc until localizer capture, intercept the localizer, intercept the glideslope, and then fly the approach to touchdown, although data collection stopped at decision height. Random wind gusts (up to 20 knots) were simulated during each approach to provide representative control disturbances that would be experienced in an operational environment. The visual scene showed zero visibility conditions above 200 feet Above Ground Level (AGL).

Demonstrations

Pilots were also provided with additional simulator time immediately after each session, and again after all the sessions, to observe PFD performance in an approach to stall condition and in any other conditions they chose. The time was also used to allow the experimenter to draw the pilot's attention to various display elements, or for the pilot to review specific symbols that were addressed in the questionnaire. Objective data were not collected during these demonstrations but subjective comments were collected via questionnaires.

Data Collection Sessions

Each pilot participated in 4 2-hour data collection sessions, one for each PFD format. At the start of each session, pilots were given a maximum of 15 minutes of practice

and familiarization, to include 3 UARs and free flight. At the completion of the practice period, the data collection trials began. During each session, the pilot flew 36 UARs, eight PICT maneuvers, 3 ILS approaches, and 1 demonstration.

Experimental Design

A repeated measures design was used for all of the PFD evaluation tasks. Each pilot participated in four separate data collection sessions, one for each format. The study was designed to analyze the data from each flying task separately because different measures were collected from each task. The ordering of PFD format presentation was counterbalanced across the pilots. The experimental design for each task type is described below.

Unusual Attitude Recoveries

For the UARs, the independent variables included: PFD Format (T-1, C-141, CONOP Attitude Format and CONOP Climb-Dive Format), Pitch Angle (+30, - 30, + 12, and - 12 degrees), and Bank Angle (three conditions are +/- 30, +/- 45, and zero degrees). These independent variables were crossed as shown in Table 1.

Table 1. The 12 Unusual Attitude Recovery Conditions flown with each of the four primary flight formats. Each condition was repeated 3 times with each primary flight format.

UAR Condition	Pitch Condition	Bank Condition
1	+30	+/- 30
2	+30	0
3	+30	+/- 45
4	-30	+/- 30
5	-30	0
6	-30	+/- 45
7	+12	+/- 30
8	+12	0
9	+12	+/- 45
10	-12	+/- 30
11	-12	0
12	-12	+/- 45

The direction (right or left) of the 30 and 45 degree bank conditions were randomly selected for each trial. Airspeed for the climb conditions was approximately 200 knots. Airspeed for the dive conditions was approximately 250 knots. Each pilot experienced three repetitions of each condition. This design provided 144 trials per subject (4 pitch x 3 bank x 4 display configurations x 3 repetitions). The ordering of conditions was partially counterbalanced with the constraint that one replication was completed for all conditions before progressing to the next one. Dependent variables for the UAR were accuracy (percentage of correct initial control inputs), reaction time and recovery time.

Precision Instrument Control Tasks

For the PICT the sole independent variable was PFD format (CDS Attitude, CDS Climb-Dive, C-141 and T-1). For statistical purposes, each maneuver was performed twice with each PFD format. Root Mean Square Error (RMS) deviations from predefined flight parameters (e.g. airspeed, altitude, bank angle, etc.) were used as dependent variables.

Instrument Landing System Approach

Three ILS approaches were accomplished with each PFD configuration. RMS deviations from glideslope, localizer, DME, and airspeed, as well as pitch and roll rates, were used as dependent variables.

Data Recording and Reduction

To allow a comparison of pilot performance across the various PFD formats, a variety of performance measures were collected for each task. These measures are described in the following paragraphs.

Unusual Attitude Recoveries

Three performance measures were collected for the UARs, all at a rate of 30 Hertz (Hz). Reaction Time was defined as the time from trial initiation to the first correct control input. Percent Correct was defined as the percentage of trials where both initial control inputs (column/yoke and throttle) were correct. Recovery Time was defined as the time used to recover from the unusual attitude to straight and level flight (Five seconds were subtracted from each recovery time to remove the 5 second criteria for automatic trial termination.)

Precision Instrument Control Tasks

Each PICT task was divided into segments for data reduction purposes, since different performance measures were relevant for different segments of the maneuver. All PICT data were collected at a rate of 5 Hz.

(1) For Vertical S-A, a *stable* window and a *transition* window were identified. The *stable* window was that portion of the maneuver where a rate climb or descent was performed. The *transition* window was defined as the portion of the maneuver where vertical direction was changing (e.g. from a climb to a dive). For the *stable* window (i.e. between 9,300 and 9,700 feet altitude), RMS vertical velocity deviation, RMS airspeed deviation and climb dive angle deviation were calculated. For the *transition* windows (i.e. altitude < 9,300 and altitude > 9,700 feet), RMS airspeed deviation was collected. Also, RMS altitude deviation was collected at the "peaks" and "valleys" of each cycle (defined as the range where climb-dive was between .25 and -.25). Finally, RMS pitch rate, RMS roll rate, RMS heading deviation and RMS bank angle deviation were calculated over the entire trial.

(2) For Vertical S-D, the *stable* and *transition* windows were identical to those for Vertical S-A, except that the *transition* window was defined as the region where both a vertical direction and heading change was being made. For the *stable* window, the following RMS deviation data were collected: vertical velocity, airspeed, climb-dive angle, and bank angle. For the *transition* window (i.e. the peaks and valleys), RMS deviations for altitude, bank angle, and airspeed were collected. Over the entire run, RMS pitch rate and RMS roll rate were collected.

(3) For the steep turns, the *stable* window was the portion of the maneuver when the pilot had stabilized the simulator in a 45 degree bank (heading > 045 and heading < 315). The *transition* window was the portion of the maneuver where the pilot was reversing head and either entering or exiting a 45 degree bank (defined as heading > 315 and heading < 045). In the *stable* window, the following RMS deviation data were collected: airspeed, vertical velocity, climb-dive angle, altitude, and bank angle. In the *transition* window, the following RMS deviation data were calculated: altitude deviation, airspeed, vertical velocity, and climb-dive angle. Finally, RMS pitch rate and RMS roll rate were collected over the entire run.

(4) For the last 60 seconds of the straight and level flying trials, RMS deviations were collected for climb-dive angle, vertical velocity, airspeed, altitude, pitch rate, roll rate, bank angle deviation and heading.

Instrument Landing System Approach

During the ILS approach, RMS DME deviation was collected from the start of the

run until the aircraft began the turn to capture the localizer (defined as the range where heading was > 270 and less than 360 degrees). RMS localizer deviation, RMS airspeed deviation, RMS pitch rate and RMS roll rate were collected after the localizer was captured and in a track mode. Glideslope deviation was collected after glideslope track mode was established. All ILS data collection was terminated at 200 feet, the altitude at which the runway became visible. All ILS data were collected at 30 Hz.

Questionnaires

Subjective data were recorded via questionnaires after each data collection session was completed. Four different questionnaires, one tailored to each PFD format, were used. These questionnaires focused on the adequacy of the proposed PFD designs, PFD element evaluations, and utility of the displays in operational conditions. A fifth questionnaire asked for a subjective comparison across the PFD designs, and addressed miscellaneous issues such as the acceptability of the cockpit geometry, display brightness and contrast, and the KC-135 aeromodel. All questionnaires are included in Appendix B. Audio and video data were recorded throughout the simulations. These data allow the review of special events that may have occurred throughout the study (e.g., simulator anomalies, etc.). Additional pilot comments were collected via audio tape during the debriefing sessions at the completion of the study.

Results

Performance Data

Unusual Attitude Recoveries

All UAR data were analyzed separately for nose-up and nose-down conditions. The nose-down condition was of primary interest because it is considered to be more critical to aircraft recovery. Also previous UAR studies have shown that the nose down conditions tend to provide more consistent and meaningful results (Cone and Hassoun, 1992, Hughes, Hassoun, Barnaba, 1992). This may be due to the greater ambiguity in trained nose-high recovery procedures.

For the nose-down conditions, reaction time and recovery time were analyzed in a 4 x 4 x 3 (Format x Pitch x Roll) repeated measures Analyses of Variance (ANOVA). No significant main effects or interactions were found for reaction time. Average reaction time was 1.025 milliseconds. For recovery time, significant main effects were found for Format, $F(3,51) = 4.17$, $p < 0.05$, Pitch, $F(1,17) = 162.13$, $p < 0.05$, and Roll, $F(2,34) = 128.88$, $p < 0.05$. Significant interactions were found for Format x Pitch, $F(3,51) = 4.76$, $p < 0.05$, and Pitch x Roll, $F(2,34) = 45.80$, $p < 0.05$. Post hoc analysis of the format by pitch interaction showed that the C-141 format produced longer mean recovery times than the other three formats in the -30 degree pitch condition. This effect is shown in Figure 6. No differences were found across formats in the -12 pitch condition. Since only effects associated with display format were of interest, no further analyses were performed on the Roll, and Pitch x Roll effects.

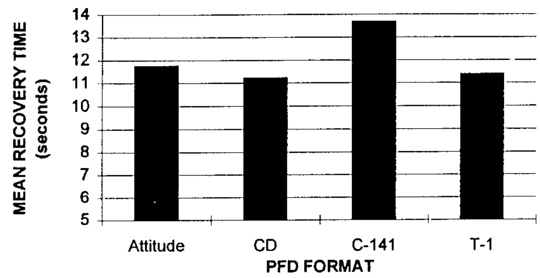

Figure 6. Mean Recovery Times for The -30 Degree Nose-Down UAR Conditions.

In order to obtain a sufficient number of trials from which to calculate percent correct, all nose-down reaction time data were collapsed across all pitch and roll conditions. Percent correct was then calculated for each display format, and analyzed in a one-way repeated measures ANOVA. No significant differences were found across formats. Overall, average percent correct was 92%.

The analysis for the nose-up conditions was identical to that used for the nose-down analysis. For reaction time, no significance was found for any effects involving PFD format. However, faster reaction times were found for the 12 degree than the 30 degree pitch condition, $F(1,17) = 11.14, p < 0.05$.

For Recovery time, significant effects were found for Format, $F(3,51) = 2.81$, $p < 0.05$, Pitch, $F(1,17) = 32.57$, $p < 0.05$, and Roll, $F(2,34) = 6.16, p < 0.05$. None of the interactions were significant. A post-hoc analysis showed that the Climb-Dive format yielded faster recovery times than the other three formats; mean recovery times for the four formats are shown in Figure 7. No further analyses were performed on the other significant effects, since they were not related to PFD format. No significant differences were found across formats for percent correct. Overall, average percent correct was 77%.

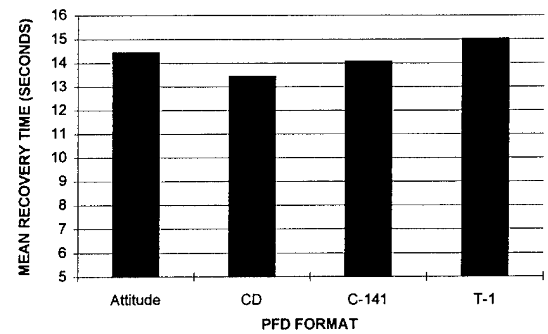

Figure 7. Mean Recovery Times for Nose-Up UAR Conditions.

Precision Instrument Control Tasks

For each PICT task, all dependent variables collected within each window were analyzed together in repeated measures Multivariate Analyses of Variance (MANOVA) using PFD Format as the independent variable. Means for Vertical S-A performance measures are included in Table 1. Univariate F tests and Duncan Multiple Range pairwise comparisons were used for post-hoc analyses.

For the *stable* window of the Vertical S-A maneuver, no significant differences were found across PFD formats. For the *transition* window of the Vertical S-A maneuver, a significant multivariate main effect was found for Format, $F(6,100) = 2.54, p < 0.05$. Post-hoc analysis showed that altitude deviation was larger for the C-141 than for the other PFD formats. For the overall Vertical S-A run, no significant differences were found across PFD formats.

For the *stable* window of the Vertical S-D maneuver, a significant multivariate effect was found across PFD Formats, $F(12, 127)$

= 2.31, $p < 0.05$. Post hoc analyses showed that the C-141 and T-1 yielded larger vertical velocity deviations and climb-dive angle deviations when compared to the Climb-Dive Format. No significant multivariate differences were found across PFD formats in the *transition* window. For the overall run, a significant multivariate effect was found across PFD Formats, $F(6,100)$ 3.04, $p < 0.05$. Post hoc tests showed smaller pitch rates for the Attitude format. Means for the Vertical S-D performance measures are shown in Table 2.

No significant differences were found across PFD formats for the Steep Turn Tasks or the Straight and Level Flying Task. Means for the Steep Turn and Straight and Level Flight performance measures are shown in Tables 3 and 4, respectively.

For the ILS approach, a significant multivariate effect was found across PFD formats, $F(6,100) = 3.06$, $p < 0.05$. Post hoc tests showed that the Attitude format yielded the lowest pitch rate, and that the pitch rate was greater for the C-141 than for the T-1 format. No differences were found across PFD formats for localizer deviation, glideslope deviation, airspeed deviation or DME deviation on the arc. Mean performance data for the ILS approaches are shown in Table 5.

Table 2. Comparison of Means Across PFD Formats For The Vertical S-A Task.

PERFORMANCE MEASURE	DISPLAY FORMATS			
	Attitude	Climb-dive	C-141	T-1
STABLE WINDOW				
RMS Vertical Velocity Indicator deviation (FPM)	162.30	171.22	183.84	188.17
RMS Climb-Dive Angle Deviation (Degrees)	.52	.55	.60	.63
RMS Bank Angle Deviation (Degrees)	1.72	1.63	1.78	1.55
RMS Airspeed Deviation (Knots)	4.11	4.36	4.41	4.40
TRANSITION WINDOW				
RMS Airspeed Deviation (Knots)	4.79	5.12	5.14	4.75
RMS Altitude Deviation (Feet) *	95.01	95.14	99.58	94.41
ENTIRE RUN				
RMS Heading Deviation (Degrees)	2.46	2.58	2.42	2.43
RMS Pitch Rate (Degrees per Second)	.22	.27	.25	.23
RMS Roll Rate (Degrees per Second)	.55	.50	.52	.50

Table 3. Comparison of Means Across PFD Formats For The Vertical S-D Task.

PERFORMANCE MEASURE	PFD FORMATS			
	Attitude	Climb-dive	C-141	T-1
STABLE WINDOW				
RMS Bank Angle Deviation (Degrees)	3.19	3.05	3.07	3.42
RMS Climb-Dive Angle Deviation (Degrees) *	.86	.81	1.17	1.04
RMS Airspeed Deviation (Knots)	8.29	7.67	7.48	7.98
RMS Vertical Velocity Indicator deviation (FPM)	312.86	283.77	375.81	357.08
TRANSITION WINDOW				
RMS Airspeed Deviation (Knots)	8.00	7.78	7.67	8.13
RMS Altitude Deviation (Feet)	101.37	105.87	108.90	101.23
ENTIRE RUN				
RMS Pitch Rate (Degrees per Second) *	1.32	1.42	1.48	1.45
RMS Roll Rate (Degrees per Second)	.65	.64	.68	.64

Table 4. Comparison Of Means Across PFD Formats For The Level Turn Task.

PERFORMANCE MEASURE	PFD FORMATS			
	Attitude	Climb-dive	C-141	T-1
STABLE WINDOW				
RMS Climb-Dive Angle Deviation (Degrees)	1.02	1.07	1.05	1.10
RMS Vertical Velocity Deviation (FPM)	375.48	330.99	345.10	391.10
RMS Airspeed Deviation (Knots)	7.77	7.34	6.80	8.07
RMS Altitude Deviation (Feet)	92.58	83.61	84.13	93.83
RMS Bank Angle Deviation (Degrees)	4.32	3.00	3.09	4.18
TRANSITION WINDOW				
RMS Climb-Dive Angle Deviation (Degrees)	1.02	1.07	.88	1.09
RMS Vertical Velocity Deviation (FPM)	531.34	531.25	619.74	574.08
RMS Altitude Deviation (Feet)	115.71	103.60	97.52	119.40
RMS Airspeed Deviation (Knots)	8.03	8.41	8.28	8.38
ENTIRE RUN				
RMS Pitch Rate (Degrees per Second)	3.03	3.11	2.99	2.96
RMS Roll Rate (Degrees per Second)	.61	.63	.57	.63

Table 5. Comparison Of Means Across PFD Formats For The Straight and Level Flying Task

PERFORMANCE MEASURE	PFD FORMATS			
PERFORMANCE MEASURE	Attitude	Climb-dive	C-141	T-1
RMS Climb-Dive Angle Deviation (Degrees)	.27	.22	.27	.25
RMS Vertical Velocity Deviation (FPM)	99.84	85.59	97.93	96.64
RMS Airspeed Deviation (Knots)	3.03	2.02	2.88	2.95
RMS Altitude Deviation (Feet)	17.47	15.98	19.87	25.78
RMS Bank Angle Deviation (Degrees)	1.25	1.13	1.24	1.16
RMS Heading Deviation (Degrees)	1.87	1.85	1.99	2.09
RMS Pitch Rate (Degrees per Second)	.16	.19	.18	.12
RMS Roll Rate (Degrees per Second)	.42	.37	.38	.38

Table 6. Mean Performance Levels For The ILS Approaches.

PERFORMANCE MEASURE	PFD FORMATS			
	Attitude	Climb-dive	C-141	T-1
RMS Localizer Deviation (Degrees)	.22	.22	.23	.22
RMS Glideslope Deviation (Degrees)	.38	.39	.39	.38
RMS Airspeed Deviation (Knots)	8.86	9.94	10.19	9.24
RMS DME Deviation (Nautical Miles)	.27	.27	.31	.24
RMS Pitch Rate (Degrees per Second) *	.35	.40	.44	.39
RMS Roll Rate (Degrees per Second)	1.23	1.36	1.34	1.27

Questionnaire Data

The primary purpose of the questionnaire data was to evaluate the individual elements of the proposed primary flight displays, to diagnose deficiencies that may have contributed to performance differences, and to identify serious safety concerns associated with a specific format. Similar questionnaires were administered after the pilots flew each of the four PFD formats.

The questionnaires evaluated each component of the PFD (Attitude Director Indicator (ADI), HSI, Airspeed Scale, Altitude Scale, Vertical Velocity Indicator (VVI)), and specific elements / characteristics of each component. These characteristics varied for each component, but typically addressed each symbol (e.g. pitch symbol on the ADI, heading marker on the HSI) and acceptability of the component for use in instrument flying (e.g. quality of trend, ability to quickly read displayed value, degree of clutter, etc.). All questions asked can be found in Appendix B.

A five point rating scale was used throughout the questionnaires. For analysis purposes, the scale was coded from 1 through 5 as shown below. This coding method is retained on the subjective results plots:

1 **Completely Unacceptable**. Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

2 **Moderately Unacceptable**. Design deficiencies that will degrade pilot performance: changes required.

3 **Borderline**. Design deficiencies that could impact pilot performance: changes desirable.

4 **Moderately Acceptable**. Minor design deficiencies that do not impact pilot performance.

5 **Completely Acceptable**. Good design as is.

Frequencies and mean ratings across all pilots were calculated for all questionnaire items, and are included in Appendix C. The appendix also provides pilot responses to open-ended questions. Comments were summarized and will be discussed in the following sections.

Mean ratings were also calculated for the two groups of pilots that participated in the study. This was of interest to the design team, and aided the interpretation of the results as they applied to the two objectives of the study. Results from the C-141 pilot group were primary applied toward the C-141 upgrade effort. The results from the non-C-141 group were primarily applicable to the head-down standard development effort. These means are shown in the appropriate sections below.

The subjective results, including ratings and comments, will first be discussed individually for each display format. The results will be discussed at a component level (ADI, HSI, etc.), unless there were meaningful findings at the element/characteristic level. In the latter case, these findings will also be discussed. After each PFD format is discussed, comparisons across PFD formats, and general issues associated with the simulation will be addressed.

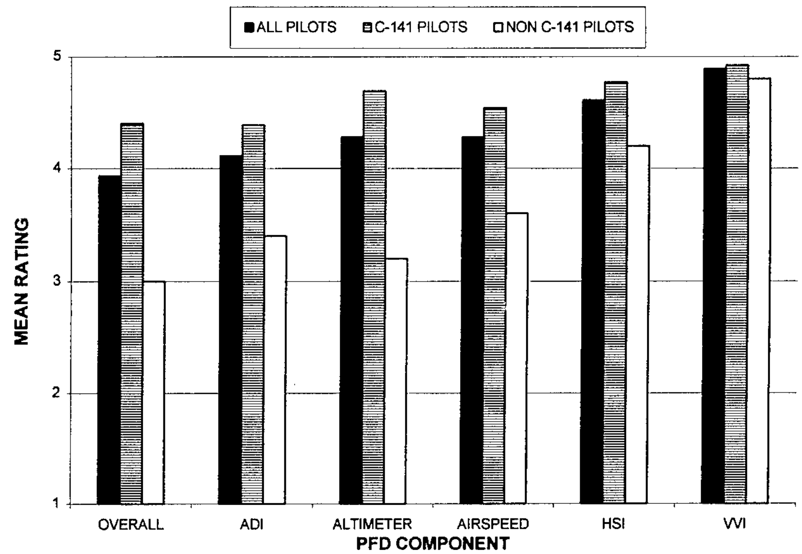

Figure 8. Mean Ratings For The Major Components of the Attitude Format.

The focus of the current results will be on the Attitude and Climb-Dive Format formats, and their specific deficiencies. The T-1 and C-141 data were primarily used for comparison purposes, as requested by the FSDG and the C-141 Program Office.

Attitude Format

Overall

Figure 8 shows the mean ratings for each major component of the CDS Attitude Format as well as an overall format rating. Overall, C-141 pilots rated the Attitude format above "moderately acceptable" and commented that the Attitude format operated in a familiar way, and added useful information, such as the climb-dive marker. Non-C-141 pilots rated the Attitude Format "borderline," on average. Both groups raised a variety of concerns with individual components of the format. These are addressed in subsequent sections.

Attitude Director Indicator (Attitude Format)

Average ratings for the ADI are provided in Figure 8. Most concerns with the Attitude Format were focused on the ADI, and the discriminability of the symbols. Degree of Clutter was the lowest rated item for the ADI. Comments indicated that clutter was especially severe during ILS approaches, where the pitch ladder, flight director bars, pitch symbol, CDM, Flight Path Marker (FPM) and the Flight Path Angle (FPA) reference line were simultaneously displayed. Many of these symbols were densely packed, colored white, and tended to blend in with each other. Some pilots considered the level of clutter to be safety concern. When asked what display elements should be deselectable, 6 pilots answered FPM, and 7 pilots answered the CDM.

While the CDM was seen as adding useful information, its mechanization was

given a low rating. Comments suggested that its dynamic nature in the Attitude Format was distracting, that an alternative color should be considered, and that it was occasionally mistaken for the primary flight control symbol. Pilots gave the FPM a relatively low rating and commented that it added to clutter without providing useful information.

The pitch/climb-dive ladder also received negative ratings and comments. Most comments related to the 2.5 degree pitch lines. Pilots felt these lines contributed to clutter, were unnecessary, and/or were often misinterpreted as 5 degree lines. Some comments indicated that the expanded scale provided more precision than was needed, and may have contributed to confusion between the 2.5 and 5 degree pitch lines.

Altitude Scale (Attitude Format)

Overall, the altitude scale was rated above "moderately acceptable" by C-141 pilots and below "moderately acceptable" by non-C-141 pilots. A variety of concerns were raised about the operational utility of the altimeter, due to the interaction of the tape and digital readout. Pilots found it difficult to obtain trend from the moving scale because of its gross scaling and because the digital readout tended to block and interrupt the scale. Since trend could not be obtained from the scale, pilots tended to primarily use the digital readout for both precision and trend information, although they commented that this strategy tended to induce workload. Further, many pilots commented that the constant movement of the digits was distracting. Similar comments were received on the radar altimeter.

Airspeed Scale (Attitude Format)

The overall design and mechanization of the airspeed scale was rated slightly lower than the altitude scale by C-141 pilots, but above "borderline" by the non-C-141 pilots. As with the altimeter, comments indicated that the digital airspeed readout tended to block the scale, and tended to induce workload. Pilots also found it difficult to obtain trend information from the scale portion of the display, and, therefore, relied heavily on the digital readout.

Horizontal Situation Indicator (Attitude Format)

The overall design and mechanization of the HSI received relatively high ratings by all pilots. Two exceptions were the heading marker design and the placement of distance information. Half of the pilots commented that the heading marker overwrote the compass rose scale, making the heading setting difficult to determine, and interfering with reading the scale itself. Several pilots recommended moving the heading marker off of the main scale, similar to the traditional "captain's bar" design used in electromechanical HSIs. Pilots also found that the placement of distance information to be unfamiliar. This tended to cause confusion and disruption of their cross-check.

Vertical Velocity Indicator (Attitude Format)

Overall the Attitude Format VVI was highly rated. All elements of the Attitude Format VVI were also rated very

highly, and very few comments were received.

Operational Issues (Attitude Format)

As shown in Figure 9, All C-141 pilots agreed that the display would effectively support C-141 operational requirements. Two of the non-C-141 pilots were either neutral or disagreed on this issue; one pilot felt that the pitch symbol was too difficult to discern and that the direction of labeling of the airspeed scale should be reversed. Several pilots felt that the format should be verified for Station Keeping Equipment (SKE), Special Operations Low Level (SOLL) II, Air Refueling and other specialized mission areas before it is incorporated into the C-141. They also expressed a concern about the ability to achieve NVG (night vision goggle) compatibility with the color display formats.

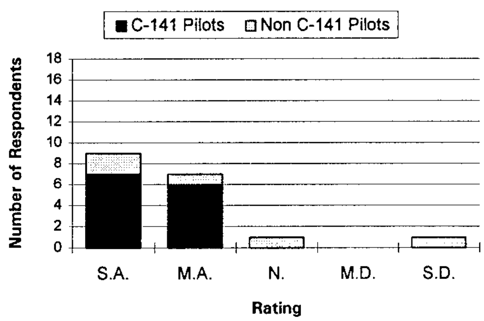

Figure 9. Responses to the Question, "The Attitude Format Will Effectively Support All C-141 Operational Mission Requirements." Ratings Range From "Strongly Agree" to "Strongly Disagree."

Safety Issues (Attitude Format)

As shown in Figure 10, all C-141 pilots agreed that the Attitude Format could be used as a primary flight reference with an acceptable level of safety. However, 3 non-C-141 pilots were either neutral, moderately disagreed, or strongly disagreed that the ADI format will effectively support all C-141 operational mission requirements. One pilot's main safety concern was that the ADI was confusing in high workload conditions. Two pilots felt that the level of clutter and scaling of the ADI could be confusing or unsafe.

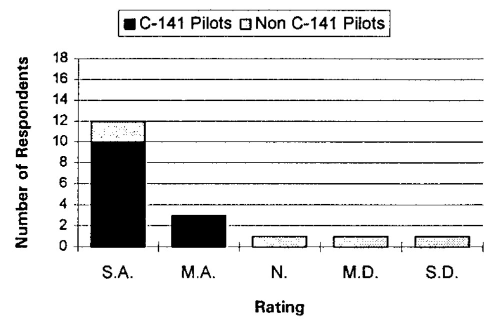

Figure 10. Responses to the Question, "The Attitude Format can be used as a Primary Flight Reference With An Acceptable Level Of Safety." Ratings Range from "Strongly Agree" to "Strongly Disagree."

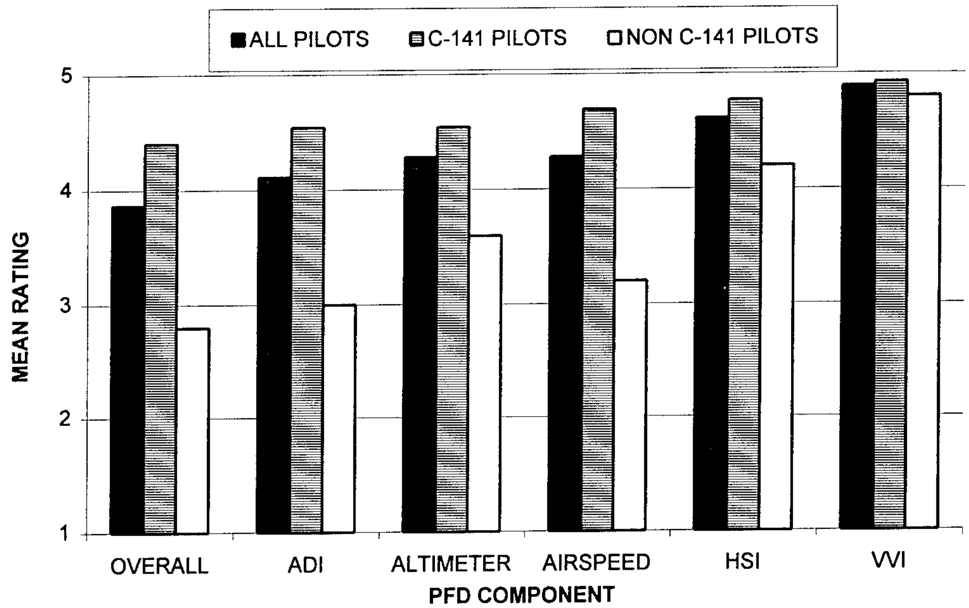

Figure 11. Mean Ratings For Climb-Dive Format Components.

Climb-Dive Format

Overall

Since many of the comments of the Climb-Dive Format were identical to the Attitude Format, the ratings and comments will not be repeated.

Overall, C-141 pilots rated the Climb-Dive Format as above "moderately acceptable," as shown in Figure 11. Non-C-141 pilots rated it as borderline. Positive comments indicated that pilots liked the climb-dive information, and that it facilitated level flight and predicting descent rates. Other pilots commented that that the CDM should not be used as a primary flight reference, that the mode was confusing during unusual attitude recoveries, or that pitch information was not sufficiently evident to the pilot. As with the Attitude Format, clutter, blending of the symbology and lack of distinctiveness of individual symbols were the primary concerns raised by the pilots about the symbology.

Operational Issues (Climb-Dive Format)

As with the Attitude Format, all C-141 pilots felt that the Climb-Dive format would effectively support all C-141 operational requirements (see Figure 12). Four of the non-C-141 pilots were either

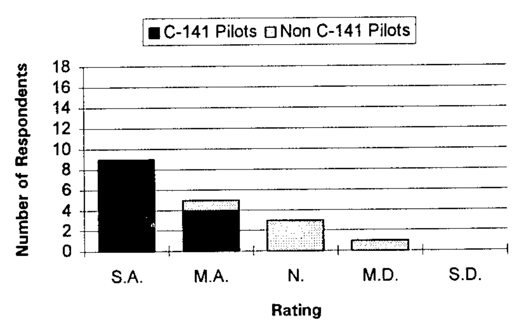

Figure 12. Responses to the Questions, "The Climb-Dive Format Will Effectively Support All C-141 Operational Mission Requirements." Ratings Range From "Strongly Agree" to "Strongly Disagree."

neutral or disagreed on this issue. Several comments indicated that the format should be evaluated in a full mission context, including SKE, SOLL II, Category (CAT) II and air refueling.

Safety Issues (Climb-Dive Format)

All but one of the C-141 pilots felt that the Climb Dive mode could be used as a primary flight reference with an acceptable level of safety (see Figure 13). One pilot felt that the ADI would be confusing in high workload conditions.

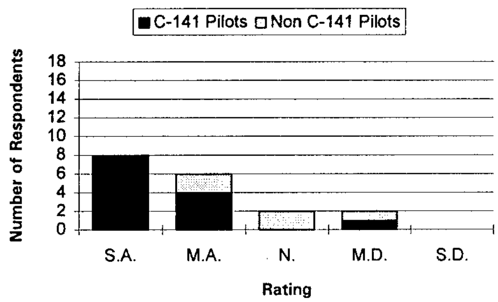

Figure 13. Responses to the Question, "The Climb-Dive Format can be used as a Primary Flight Reference With An Acceptable Level Of Safety." Ratings Range from "Strongly Agree" to "Strongly Disagree."

Another pilot pointed out that the Climb-Dive Format may be unsafe for unusual attitude recoveries. In the Climb-Dive Format, the CDM served as the primary control reference, and as the point of reference for the movement of the climb-dive scale. Concern was raised that the Climb-Dive Format may lead the pilot to making an incorrect recovery control input particularly in extreme conditions (e.g. stall conditions), where climb-dive showed level flight or a dive condition, and the miniature aircraft symbol showed a high pitch angle (i.e. angle of attack is large).

A related result was found in the demonstration of a near-stall condition during the debriefing session. During the demonstration flights, the climb-dive and Attitude Formats were shown side by side in a nose-up/descending flight path condition. (An example of this configuration is shown in Figure 2.) When asked, five of the pilots felt they would have misinterpreted the Climb-Dive Format as a nose down condition, and 3 of the pilots felt they would have made an incorrect recovery input.

C-141 Analog Format

Overall

Mean ratings for the C-141 Format components, as well as an overall rating for the format, are shown in Figure 14. Overall, the C-141 format was rated very highly (nearly "completely acceptable") by the C-141 pilots. However, the non-C-141 pilots rated the design below "moderately acceptable." No significant safety or operational issues were identified with this format.

Attitude Director Indicator (C-141 Format)

C-141 pilots rated the C-141 ADI above "moderately acceptable." Non-C-141 Pilots also rated it above "moderately acceptable. Comments indicated that a more precise pitch scale would be desirable, and that performance was less precise with this display. On the other hand, pilots felt that the relatively large field of view improved situational awareness during unusual attitude recoveries.

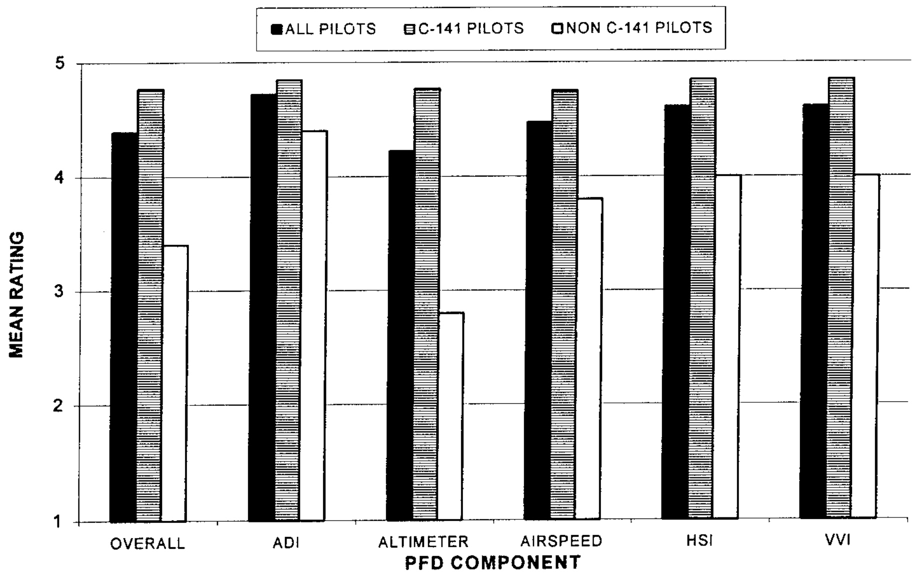

Figure 14. Mean Ratings For The C-141 Format Components.

Altitude Indicator (C-141 Format)

Overall, the C-141 altitude indicator was rated nearly "completely acceptable" by C-141 pilots and below "borderline" by non-C-141 pilots. Positive comments, mostly from C-141 pilots, indicated that the design provided superior trend information. Negative comments, mostly from non-C-141 pilots, indicated that the two-scale design can interfere with quickly reading a precise altitude, and may increase the potential for misinterpretation.

Airspeed Indicator (C-141 Format)

Overall, the airspeed indicator was rated nearly "completely acceptable" by C-141 pilots, and below "moderately acceptable" by non-C-141 pilots. Comments, mostly from non-C-141 pilots, indicated that the design did not facilitate quick acquisition of airspeed, and greater precision would improve the utility of the display.

Horizontal Situation Indicator (C-141 Format)

The C-141 HSI was rated as nearly "completely acceptable" by C-141 pilots, and "moderately acceptable" by non-C-141 pilots. Comments indicated that better use of color coding and greater precision would be desirable.

Vertical Velocity Indicator (C-141 Format)

The VVI was rated as nearly "completely acceptable" by C-141 pilots, and "moderately acceptable" by non-C-141 pilots. Comments indicated that trend presentation could be improved, and a few pilots desired a greater scale range.

T-1 Format

Overall

Mean ratings for the T-1 PFD major components are shown in Figure 15.

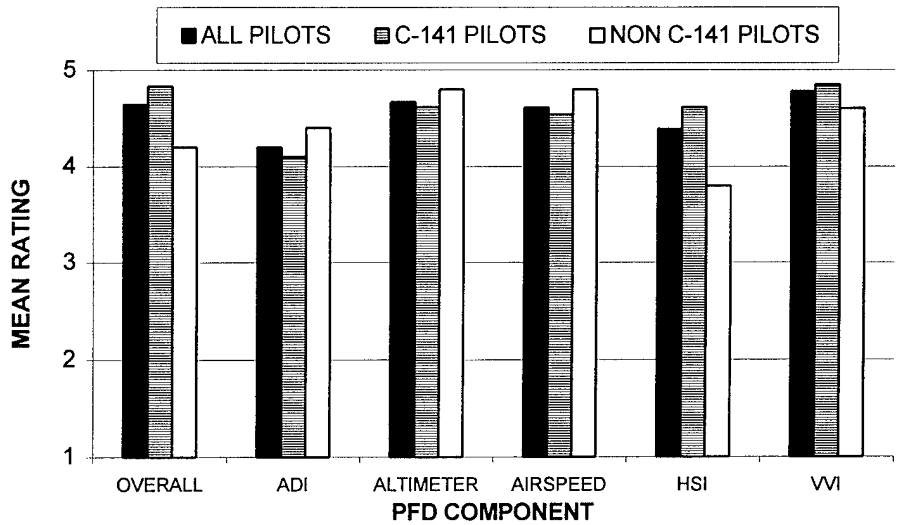

Figure 15. Mean Ratings For The T-1 Format Components.

The overall T-1 format was rated highly by both the C-141 and non-C-141 pilots (see Figure 15). General comments indicated that it could be read easily and quickly, and provided good trend information. No significant safety or operational issues were identified with this format.

Attitude Director Indicator (T-1 Format)

Most elements and the overall design of the T-1 ADI were highly rated. Exceptions were the bank scale and the Angle Of Attack (AOA) indicator. Several pilots commented that they were not used to using a bank scale at the top of the ADI. Several pilots also commented that they were not clear on how to interpret the AOA indicator.

Altitude Indicator (T-1 Format)

The T-1 altimeter was also rated very highly by all pilots, with averages approaching "completely acceptable. No significant comments were provided.

Airspeed Indicator (T-1 Format)

The T-1 airspeed indicator, and its elements were rated very highly by all pilots. However, pilots comments indicated that the pointer should be made more prominent. One suggestion was to fill the pointer in with a solid color. Several pilots also commented that ground speed should be added to the indicator.

Horizontal Situation Indicator (T-1 Format)

Of the T-1 components, the HSI received the lowest ratings. C-141 pilots rated it between "moderately and completely acceptable." Non-C-141 pilots rated it below "moderately acceptable." Several pilots commented that the head and tails of the bearing pointers were difficult to distinguish, because NAVAID symbols, rather than arrows, are used as the pointer heads. In other comments, pilots indicated that they felt the compass rose was too small, that the course arrow was too large and blocked the scale, that the course readout should be moved to a different location, and that an alternative

color coding scheme should be used. No consistent color scheme was suggested by the group of pilots.

Vertical Velocity Indicator (T-1 Format)

As with most other T-1 components, all pilots rated the VVI design near "completely acceptable." Comments indicated that pilots felt the display provided good trend information and could be easily interpreted.

Comparison Questionnaire

When asked which display was most preferred and least preferred, 10 of the 13 C-141 pilots rated either the Attitude Format (5) or Climb-Dive Format (5) as the most preferred display, while 3 of the C-141 pilots rated the CDS formats as the least preferred display (1, attitude; 2, Climb-Dive). Four of the five non-C-141 pilots rated the T-1 display as the most preferred format; three non-C-141 pilots rated the Climb-Dive Format as the least preferred format.

Simulation Environment

All but one pilot felt that the tasks used in the evaluation adequately exercised the capabilities of the proposed primary flight display. One pilot felt that tasks did not make realistic use of the heading marker.

When asked what factors increased their workload during the testing, nearly all pilots mentioned that the flight model was poor and very difficult to fly the precise maneuvers. Most pilots (15) felt they were able to adapt to it for purposes of the test. However, three pilots indicated that some display elements were difficult to evaluate due to the poor flight model. Other simulator characteristics, such as display quality, cockpit geometry and others were rated between moderately and completely acceptable.

Discussion

Implications for the Cockpit Upgrade Program

The primary objective of the current study was to assess the suitability of the proposed CDS formats for use as a primary flight reference in the C-141 aircraft. The criteria for "suitable" was established at the start of the evaluation. The CDS design must provide equal or better performance than the current C-141 design. The questionnaire data were used primarily to identify display deficiencies, and explain performance results.

Most performance data did not show any significant differences across the display formats. Where differences between the CDS and C-141 formats were found, performance with the CDS formats was always more precise (i.e. "better") than with the C-141 display. Thus, the proposed CDS displays met the criteria of "equal or better" than the C-141 format.

The subjective data from the C-141 pilots also generally indicated that the formats were "suitable" as a primary flight reference for the C-141. However, a variety of deficiencies were noted that should be resolved before the format is incorporated into the aircraft. These changes are discussed in the "Recommended Design Changes" section.

The subjective data also suggested that a safety risk may be introduced by using the CDS Climb-Dive Format. Specifically, the display may be misinterpreted in the extreme flight conditions, such as a stall. Lack of experience with climb-dive indicators may exaggerate this problem. Concerns were also raised about the potential confusion associated with having both the Attitude and Climb-Dive formats available and pilot selectable. In high-workload conditions, the potential exists for misinterpretation of the selected mode. As a result of these concerns, it is recommended that only the attitude format be incorporated into the C-141.

Implications for the Head-Down Display Standard

A secondary goal of this effort was to collect subjective and objective data that would support the development of an Air Force Head-Down display standard. To address this goal, the T-1 format was included in the evaluation. The Climb-Dive Format also provided data associated with a rather radical departure from traditional display formats, that could be considered in the development of a standard.

The T-1 format was selected as the performance baseline because it is based heavily on an electro-optical format that has been in use for several years in commercial aviation, is currently in use in an Air Force trainer aircraft, and is FAA certified. On all performance measures, the CONOP formats yielded equal or better performance to the T-1 display formats.

While C-141 pilot ratings are of most interest when considering suitability of a display for the C-141 aircraft, a standard display development effort must consider inputs from pilots with a variety of backgrounds. The five non-C-141 pilots were included in this test for this reason. Ratings between the two groups appeared to sharply differ on the CONOP and C-141 display formats. The non-C-141 pilots consistently rated the T-1 and its components as the most preferred format, and a superior design to the other formats. Additionally, they rated the CDS formats as "borderline." The C-141 pilots also rated the T-1 and its components very highly, but also rated the CDS formats very highly. The differences between the groups may be a result of the pilots' flying experience. Many of the CDS features have a strong similarity to the current C-141 electro-mechanical displays. The T-1 bears a strong similarity to the electromechanical instruments flown by the non-C-141 pilots.

The results suggest that the CDS format, with improvements, could be suitable for use as a baseline for the standard head-down format. Potential solutions have been identified to address the majority of the deficiencies identified in the study, and are discussed in detail in the "Recommended Design Changes" section. One caution is that the CDS display was designed primarily to address C-141 interests, and may not be as appropriate for other aircraft.

Throughout the design and evaluation process, a variety of general lessons learned regarding primary flight display design became evident. Many of these have relevance to the head-down stan-

dard design effort, and some have particular relevance to electronic display formats. These are discussed in the following paragraphs.

Clutter was identified as one of the most significant design deficiencies. Resolution of the clutter problem can be achieved through careful selection of symbol sizes, stroke widths, symbol designs/integration, and the application of color coding. Also, care should be exercised when determining what information should be presented. The clutter issue appears to be a more severe problem with computer generated displays because symbols are not separated in depth. Also, the designer is more tempted to add more symbology to the display because of the ease in which it can be readily added via software modifications.

ADI field of view surfaced as a significant issue during the test. The expanded scaling (reduced field of view) shown on the CDS formats tended to exaggerate the apparent aircraft response to control inputs. This was most noticeable by the C-141 pilots who are accustomed to a very large field of view that is relatively insensitive to minor pitch changes. While the more expanded scale yielded more precise flying, this benefit must be weighed against the situational awareness benefits associated with a large field of view.

The CDS airspeed and altitude formats were identified as deficiencies in the evaluation. These instruments must effectively provide both precision and trend information. The CDS design is intended to provide precision with the digital readout and trend with the moving scale. However, pilots could not effectively extract trend information from the tape, due to its scaling and its partial obscuration by the digital readout. Therefore, pilots relied on a digital readout for trend, an approach that violates human factors design principles (MIL-STD-1472D, 1989; Wickens, 1984). Further, the constant motion of the digital readouts was distracting and annoying, thereby interfering with an efficient cross-check. Alternative designs or modified designs (e.g. counter-pointer type displays) should be considered for purposes of the head down standard.

Finally, the current study results emphasized the role that training and experience may have on the evaluation of standard head down display design concepts. There is strong evidence to suggest that ratings differed significantly as a function of pilot experience. For example, C-141 pilots appeared to be comfortable with tape altitude and airspeed formats (in the C-141 and CONOP designs), while the non-C-141 pilots appeared to prefer round-dial indicators. Similarly, some of the deficiencies, such as the confusion of 2.5 degree pitch lines with 5 degree lines, were only identified by C-141 pilots. Most likely, this was a problem for the C-141 pilots because the 2.5 degree lines in the CDS format strongly resembled the 5 degree lines in the current C-141 ADI.

Also some items were rated poorly simply because the pilot did not understand a "new" symbol, or did not have sufficient experience with it. These results suggest a need to consider previous training and experience effects when developing designs and interpreting evaluation findings, especially when

those designs are radically different and unfamiliar to the user population.

It should be noted that the current study results will not be sufficient for validating the C-141 as a head-down standard, mainly because of the number of deficiencies identified. Correction of these deficiencies will result in a rather extensive modification to the display format. When implementing such changes, there is a risk of creating new deficiencies or of not resolving the original concern. Therefore, additional evaluation of the modified design is recommended.

Implications for Pilot Performance in Operational Conditions

It is of interest to understand the nature of and the reasons behind the performance differences obtained in this study. This understanding can be helpful for the current and future design and development efforts, and can possibly predict real-world performance with the proposed formats.

The results from the current simulator evaluation cannot be used to predict absolute performance levels in real-world conditions. A variety of factors, including aerodynamic model limitations, lack of "seat of the pants" cues and other simulator limitations, make this impossible. However, from an experimental design perspective, we have held these factors constant across the display formats, thereby compensating for their effect. Therefore, we are confident that a similar pattern of results would be found in real-world conditions. The following discussion should be interpreted in this light.

One notable result of the performance data analysis is that, while a large number of individual measures were collected, very few showed any significant difference. This result suggests that, generally speaking, differences between the formats were minor, and any of them would provide acceptable performance in real-world conditions. However, we also recognize that the poor aerodynamic model may have induced enough variability in the data to reduce the sensitivity of some performance measures.

Unusual Attitude Recovery Results

For the UAR tasks, performance on the UARs showed that the C-141 had longer recovery times for some nose-down conditions, and that the Climb-Dive Format had shorter recovery times for some nose-high conditions. The shorter recovery times with the Climb-Dive Format are probably due to fact that the criteria for recovery was based on climb-dive angle rather than pitch, and the Climb-Dive format uses climb-dive angle as the primary control reference. The longer recovery times for the 30 degree nose-down condition may be due to differences in ADI field of view. The larger field of view of the C-141 format may have resulted in less responsiveness to control inputs, thereby increasing the potential for overshooting the criteria window for straight and level flight, and increasing total recovery time.

The UAR data are critical for determining suitability of the formats for use as a PFD. While the C-141 rarely has the need to recover from unusual attitudes, the primary flight reference must provide an immediately discernible attitude reference, and the information required to

immediately determine the proper control input to recover the aircraft. The lack of significant differences in reaction time across the formats suggests that the CONOP formats will provide at least equal capability to the current C-141 for recovery.

The UAR performance data, as a whole, suggest slightly improved performance with the CDS or T-1 formats over the C-141. This is probably due to the lower precision provided by the C-141 format. This result would suggest that greater precision is desirable. However, greater precision will only be beneficial to a point. Beyond some threshold, increased precision will necessarily reduce global situational awareness provided by an ADI, and will probably increase workload. The current results suggest that the current proposed CDS formats may have exceeded that precision threshold. Although the CDS pitch scale provided more precision than the T-1, performance generally did not differ between the two formats. Thus, the T-1 ADI scaling appears to be a good balance between precision and situational awareness.

Precision Instrument Control Tasks and Instrument Landing System Tasks

In most cases, performance differences across CDS, T-1, and C-141 formats for the PICT and ILS tasks appear to be a result of differences in ADI scaling. The C-141 ADI shows a total of nearly 90 degrees field of view, while the CDS formats show less than 30 and the T-1 shows around 45 degrees. The added precision of the CDS and T-1 ADIs may have allowed the pilots to more precisely achieve and maintain specific pitch and power settings for the PICT tasks. More precise control would lead to more accurate maintenance of flight parameters, less overshoot, and smaller corrections, and would account for the observed performance differences. Additionally, the expanded fields of view provided better display response to control inputs, which may have helped to reduce over-controlling. Subjective comments support this interpretation. Pilots indicated that greater precision was desired on the C-141 format, and a few pilots felt their performance was less precise with the C-141 format.

A similar explanation can be made regarding the differences in pitch rates found in the Vertical S-D and ILS approaches. The expanded field of view may have provided greater sensitivity to control inputs resulting in less over-controlling. This may also explain why this effect was found for pitch rate but not roll rate.

Operational Implications

As stated previously, a similar pattern of performance differences to the current study would be expected in operational conditions. The performance differences were statistically significant but rather small in the simulation context. These differences may become more apparent, however, in critical operational conditions.

An issue that was not directly addressed in the current study was the potential workload penalty associated with the more precise CDS format. The more precise CDS format (i.e. digital altitude, digital airspeed, digital heading, ex-

panded ADI scale) allows the pilot to detect smaller deviations from flight parameters, and correct those deviations. In fact, several pilots commented that the greater precision may tend to influence their "personal" performance criteria, making it more strict. However, the added precision may produce a corresponding increase in workload, since the pilot spends more time attending and correcting to relatively small parameter deviations. Comments reflected this concern with the CDS format. This workload penalty is unnecessary and undesirable unless the improvement in flying precision is considered operationally important.

Note also that the results of the current study apply most directly to instrument flying tasks, where the pilot is attempting to maintain a high level of precision. Although there are operational tasks where this type of flying is required (precision approaches, formation flying, airdrop missions, etc.), there are other conditions that require relatively low precision flying (e.g. high altitude cruise), or a monitor function to be performed by the pilot (e.g. cruise segments with autopilot on). Since these conditions are probably less demanding from a display perspective than instrument flying, we feel confident that our results can be generalized to these conditions. However, we would still recommend verification through simulation in a mission context.

Recommended Design Changes

Since the subjective ratings appeared to differ between C-141 and non-C-141 pilots, the determination of the suitability of the CDS format for use in the C-141 was based primarily on the C-141 pilot ratings. This group rated all of the displays as "moderately or completely acceptable," confirming the performance results that any of the displays were acceptable for the tasks flown. However, a variety of significant concerns with the CDS design were identified, some of which have safety implications. Most of these concerns were serious enough to warrant correction before incorporation into the C-141.

The changes discussed below were made based upon the current study results and are primarily intended to improve the design for incorporation into the C-141. These proposed changes were identified based on pilot comments and consultation with a variety of subject matter experts, including the AWG and FSDG. Note that some of the changes are based on information requirements that are unique to the C-141. However, all of the changes should receive serious consideration during the development of the head-down standard. Proposed design changes are shown in Figure 16.

Use of Attitude Mode

Due to the potential for misinterpretation of the Climb-Dive mode in extreme conditions (discussed under "Implications for the Cockpit Upgrade Program") it is recommended that only the Attitude Mode be incorporated into the C-141 aircraft. The design changes

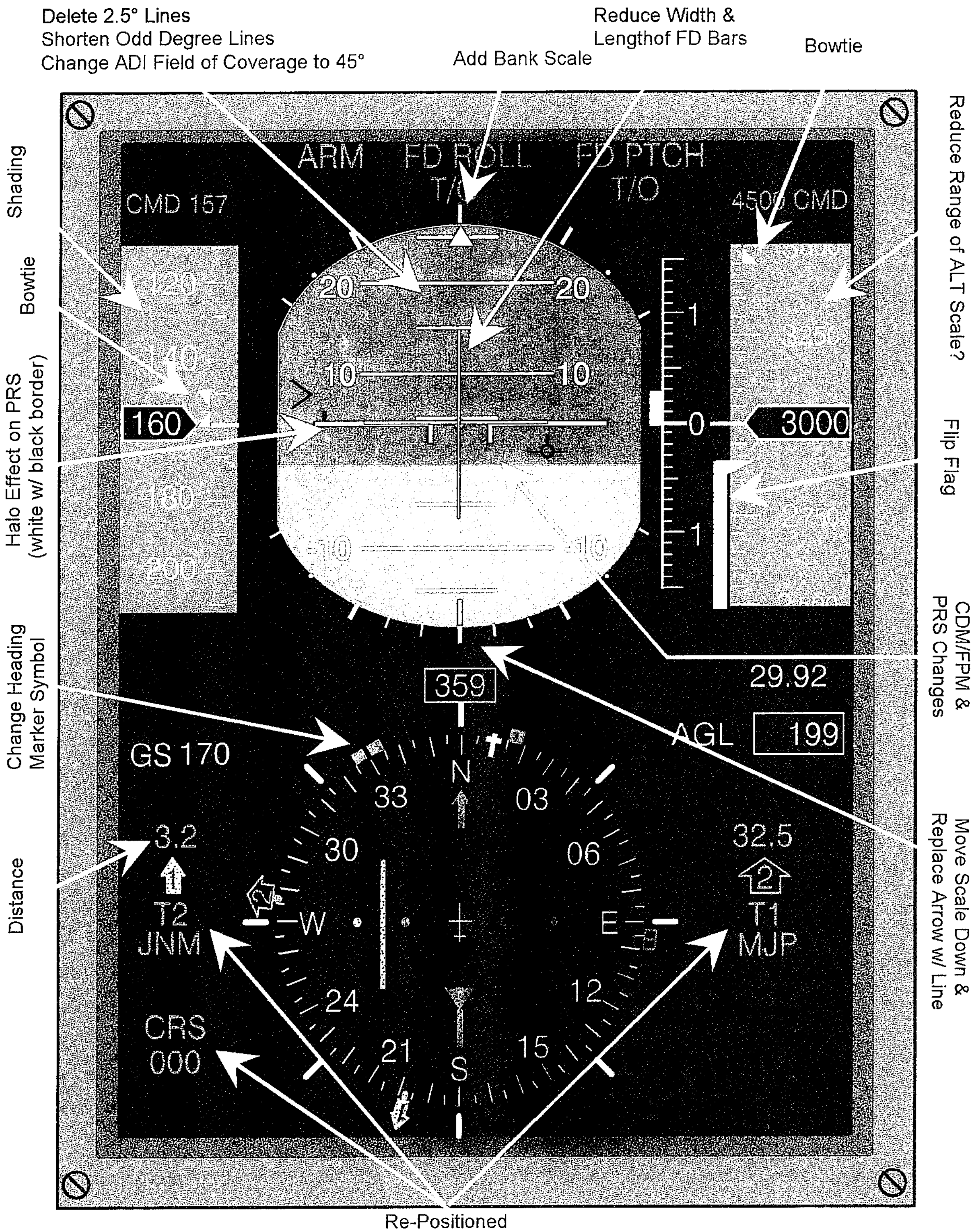

Figure 16. Conceptual Designs For Proposed Changes To The Attitude Format

described below are intended to apply to the Attitude Mode.

Climb-Dive Marker

The size of the tested design conformed to the MIL-STD-1787B requirements, but was found to be distracting, to add clutter, and was sometimes confused with the primary flight reference. The following changes should help to reduce clutter and emphasize the CDM's role as a secondary reference

- Change color from white to black.
- Reduce size of the CDM to match flight path marker.
- Add DAMU option to select CDM, FPM or neither.

Miniature Aircraft Symbol

While the miniature aircraft symbol was well received, we recommend it be modified as part of the effort to reduce clutter, improve its discriminability, and emphasize its role as the primary flight reference. Specifically, we recommend the following changes:

- Reduce stroke width.
- Change symbol color from black to white with black outline ("shadowing").
- Reduce size of gap between "wings" to match new climb-dive marker size.

Flight Path Marker

The primary concern with the flight path marker was that it contributed to clutter, and was difficult to interpret (probably due to inadequate training). We believe the option to display flight path should be retained as a DAMU selection. Specifically, we recommend:

- Provide the capability to select either the climb-dive marker or flight path marker, but not both.

Pitch Scale

Pilots commented the scaling was too precise, and exaggerated apparent response to control inputs. Also, pilots confused the 2.5 degree lines for 5 degree lines. The T-1 was used as a guideline for selecting an alternative scaling, and additional changes are recommended to help reduce ADI clutter. Recommendations are to:

- Delete 2.5 degree lines.
- Change ADI field of view to match that used for T-1 (45 degrees total).
- Reduce length of 5 degree lines.

Bank Scale

The following changes are recommended to improve the zero bank reference condition for the top scale, and to improve readability of the bottom bank scale.

- Add an abbreviated bank scale at the top of the ADI, including a zero

reference mark and 0, 30, 45, 60 tic marks.

- Delete 5 degree references on bottom scale.

- Move bottom bank scale to outside of ADI ball, and use line style pointer

Pitch and Bank Steering Bars

Recommend the following design changes be made to help reduce clutter, aid discriminability of different symbols, and help prevent the bars from overwriting the miniature aircraft symbol:

- Reduce length and width of pitch and bank steering bars.

Heading Marker

In an effort to improve the readability of the heading marker setting, and to prevent its obscuration of the compass rose, the following design changes are recommended:

- Implement traditional "captain's bars" design.

- Display heading marker on outer edge of compass rose.

Navigation Data Placement

Pilots commented that the nontraditional placement of the DME and course information tended to disrupt their normal scan pattern. We recommend making the following changes:

- Remove "DIST" identifier.

- Place DME distance information above each bearing pointer identifier.

- Move both bearing pointer 1 and 2 identifiers to the upper left and middle right of the HSI, respectively.

- Move the course digital readout to the lower left side of the HSI.

- Move alert radar altitude to lower right corner.

Altimeter Scale / Radar Altitude

Mission information requirements (i.e. 2000 foot range) and limited display space preclude many alternative designs. The following may help reduce perceived clutter, aid the discernability of the altitude scale from other components, and thereby improve usability of the altimeter:

- Add gray shading to the display area behind the altitude scale and airspeed scales such that all relevant altitude and airspeed information is grouped together

- Make digital readout move in a "drum counter" fashion.

- Flip the radar altitude thermometer indicator horizontally

Mach Indicator

Several pilots commented that 3 digit precision was not necessary for the Mach indicator.

- Recommend changing displayed mach precision to 2 significant digits.

Airspeed and Altitude Command Markers

Pilots raised a concern that the command markers were blocked by the digital readouts as the commanded value was approached. Recommend the following to resolve this concern:

- Implement "bow tie" style command markers for the airspeed and altitude scales.

Conclusions And Recommendations For The Primary Flight Display Evaluation

The findings in the current study showed that both CDS formats provide equal or better performance than the C-141 format. In most cases, the performance differences are probably due to the large differences in ADI field of view. Generally speaking, the questionnaire data from the C-141 pilots was consistent with the performance results. The CDS ratings were very similar to the C-141 ratings by the C-141 pilots. CDS ratings by the non-C-141 pilots appeared to be significantly lower, with the T-1 being the most preferred for this group. Both groups identified numerous deficiencies with the CDS formats, some of which have potential safety impacts. The correction of these deficiencies may enhance safety and will improve pilot acceptance of the designs.

The results suggest that the general design of the CDS Attitude Format would be suitable for use as a primary flight reference in the C-141. However, the design deficiencies should be resolved before it is incorporated into the C-141. This resolution should include further evaluation, and, if feasible, flight test. The format also appears to be suitable for a baseline head-down standard display once it is optimized.

Based on potential safety concerns raised with the Climb-Dive format, we recommend it not be considered for incorporation into the C-141 or as a baseline standard at this time, pending further research addressing the potential for misinterpretation in extreme flight conditions.

DISPLAY AVIONICS MANAGEMENT UNIT EVALUATION

Objectives

The objective of the DAMU evaluation was to evaluate ease of menu navigation and adequacy of menu functions in a part-task scenario that was independent of flying tasks. The following DAMU menu system designs were evaluated through performance and subjective rating data:

(1) CONOP DAMU Design. This format, described in the C-141 CONOP Revision B, is the baseline design being proposed for incorporation into the C-141.

(2) WL/FIGP DAMU Design. This was a design developed by the Cockpit Integration Division. It provides the identical functionality as the CONOP design, but incorporates alternative menu operation and navigation conventions.

Testing took place using a fully functional DAMU menu system, and consisted of a series of scripted menu navigation tasks, most of which were embedded in a mission context. Pilots did not fly the simulator while performing these tasks.

Performance data were collected during each testing session and were used to compare both designs and to identify gross design deficiencies within each design. Questionnaire and subjective workload data using SWORD (Subjective Workload Dominance) were also collected. These data were used to identify and diagnose deficiencies within each design. Debriefing session comments supplemented the questionnaire data in identifying design deficiencies.

Method

Subjects

Twelve pilots participated in the study. These pilots were part of the group that participated in the PFD part-task study. The following experience levels were represented: 2 copilots, 3 first pilots, 3 aircraft commanders and 4 instructor pilots.

Apparatus

Transport Aircraft Cockpit Simulator

An operational DAMU system, that allowed navigation throughout the entire menu structure, was used for testing. This DAMU system was located inside the TRAC simulator and was approximately the same size and in approximately the same glareshield area as was specified for implementation into the C-141. Only the pilot's station was configured for DAMU testing.

The DAMU system allowed for configuration changes to be made to static a PFD and SFD which were also located inside the TRAC simulator. The PFD and SFD interfaces existed only to incorporate realism into the study and to provide feedback regarding activation of specific DAMU menu options. The DAMU system software was designed to allow response time and error data to be collected for analysis.

Display Designs

Both display designs the CONOP design and WL/FIGP design consisted of two display screens with each screen having four line select keys on either side, providing a total of eight line select keys per screen. The line select keys allowed for either: 1) the selection and/or activation of menu line item options, or 2) another page of submenu options. Figure 17 illustrates the DAMU screen and key layout.

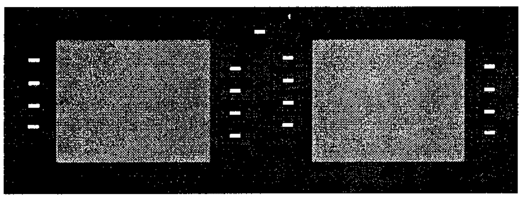

Figure 17. DAMU Screen Layout

Functionality

Both display designs provided identical functions having the same primary menu pages and associated menu elements. These primary menu pages were the: 1) Nav Select Page, 2) Status Page 3) PFD, 4) SFD, 5) Display Control, and 6) BIT (Built In Test). All pages, except the BIT page were encompassed in the part-task evaluation.

An overview of the functionality of each of these primary pages is provided below. Appendix D contains a detailed functional description of the DAMU menu elements within each of the primary menu pages.

Nav Select / Status Menu: Provides the capability to control navigation system input to the Automatic Flight Control System (AFCS) and for controlling flight director operation. Includes: mode selection of the AFCS and flight director, selection of heading and attitude source, and assignment of navigational aides to Bearing Pointers 1 and 2.

PFD Menu: Provides the ability to independently control the configuration of the PFD.

SFD Menu: Provides the ability to independently control the configuration of the SFD.

Display Control Menu: Provides the ability to control the configuration and display mode of the DAMU displays and to select the processor unit, location and display mode for the PFD and SFD.

The major difference between the two display designs was in menu navigation; that is, the "path" that is traveled through the menu system to accomplish a given action. Two distinct differences existed between the two designs:

1) The CONOP design typically toggled between displayed menu options if only two options were available; and displayed options on the right DAMU screen if more than two options existed. The WL/FIGP design used a rotary toggle method for selections of three options or less. The rotary toggle allow the user to scroll between menus options with only one option (active) being displayed at any given time. If more than three options were available, they were displayed on the right DAMU screen.

2) The two designs also differed in how MAIN MENU and Fuel Savings Advisory System (FSAS)/CDU REPEAT pages were accessed and displayed. The

CONOP design presented the Main Menu on the left screen as the highest level in the menu hierarchy. The WL/FIGP design presented the Main Menu on the right DAMU screen as a "go to" page which allowed the user to directly go to any primary menu page without going to a higher level on the menu hierarchy.

Other differences between the two designs included the location of menu options and labeling of menu titles and elements within each of the primary menus. These differences are outlined in Table 6. Appendix E graphically depicts the structural layout of both DAMU menu systems.

Table 7. Design Differences

AREA OF DIFFERENCE	CONOP DESIGN	WL/FIGP DESIGN
Menu Navigation:		
Main Menu / FSAS CDU Page	Located on the left DAMU screen as a highest level in the menu hierarchy.	Located on the right DAMU screen as a "go to" page in the same level of the menu hierarchy
Status Page	Same selections as NAV SEL page but also displays status information	No separate Status Page. Status information presented on the NAV SEL page
Option Selection: Menu Element Labels	Except on Nav Select Page and some instances on Display Control Page, toggle through displayed options	If 3 options or less, rotary toggle through options. Only active option displayed.
Primary Flt Display	PFD	PFD CONFIG
Secondary Flt Display	SFD	SFD/MAP CONFIG
Display Control	DISPLAY CONTROL	DIS CNTRL
Nav Select Menu		
Attitude Reference	ATT	ATT REF
Heading Reference:	HDG	HDG REF
PFD Menu		
Heading Reference	HDG	HDG REF
Altitude Scale	SCALE	ALT
Heading	SYN MAG- YES / NO	HDG- MAG / TRUE
Mode	MODE- ATT / FLIGHT PATH	MODE- ATT / CD
Climb Dive / Flight Path Marker	CDM	CDM/FPM
SFD Menu		
TACAN Stations Display	TACS	TACAN
DISPLAY CONTROL Menu		
Inboard Display Unit	INBOARD	INBRD
Outboard Display Unit	OUTBOARD	OUTBRD

Experimenter's Console

The experimenter's console provided the capability for the experimenter to select the following test parameters: subject number (pre-assigned to experimental condition), task type, and trial number. The display design was automatically updated upon selection of subject and trial number. The console presented task commands for each trial to allow the experimenter to read task descriptions to the subject. Ordering of task trials was automatically updated upon completion of previous task trial. The experimenter initiated the start of a trial from the console, and at the end of each trial, was provided feedback that the trial has been completed.

Procedure

Training

A high-level overview of the DAMU system and evaluation procedures was given as part of the introductory briefing. Following this briefing, subjects received a one hour hands-on briefing in the TRAC simulator. This training involved stepping through and giving a functional description of each the DAMU menu elements. The purpose of the hands-on briefing was to train the subjects on DAMU functions and allow them to observe DAMU functional interactions with other systems. The DAMU design used in the hands-on training was the counterbalanced design format they would be given in the first testing session.

Additional training specific to each DAMU menu design (i.e., CONOP or WL/FIGP) was given just prior to testing in the TRAC simulator. This training focused mostly on navigating through the menu system; and stepping through each DAMU menu element. Subjects were then allowed approximately 15-20 minutes to step through the menu system on their own. The training concluded with a pre-test of 24 tasks (6 per menu page). Incorrect tasks were reviewed and tested again until the subject completed all tasks successfully.

Testing

Testing consisted of the scripted-role playing exercise, completion of questionnaires and Subjective Workload Dominance (SWORD) forms. The scripted-role playing exercise consisted of 48 discrete task trials. Twenty-nine of the 48 trials were embedded within a time-based sequence of mission events that included Standard Instrument Departure (SID), Enroute, and Approach segments. The remaining 19 trials were random events that exercised navigation across various menu pages. A list of these 48 task trials is contained in Appendix F.

The DAMU screens were blanked prior to each task trial. After the experimenter instructed the subject to perform a specific DAMU task, the subject pressed a centrally located key on the DAMU (PFD BASIC key) to indicate that the task was understood and to signify the start of the trial. The same DAMU key was used to signify trial completion and as a cue to blank the screen for the next trial.

Upon completion of the scripted role-playing exercise for each design, subjects responded to a questionnaire (Appendix G) that required subjective assessments to be made of DAMU menu design and operational adequacy for each menu page. Upon the completion of both design testing sessions, pilots were presented a SWORD rating sheet (Appendix G).

Experimental Design

Each subject completed four identical blocks of 48 trials for a total of 192 trials. The first two blocks of 96 trials were with one DAMU design and the second two blocks of 96 trials were with the other DAMU design. Three independent variables were investigated: 1) DAMU design (CONOP Rev. B and WL/FIGP), 2) experience (block 1, block 2), and 3) task type (Nav-Ref, Nav-AP, Nav-BP, PFD, SFD and Display Control).

Task type was counter-balanced within each block of 48 trials, with each task type represented a total of 8 times. The following is a description of each task type:

> **NAV-REF** tasks involved the change of attitude or heading source from the Nav Select or Status Menu page.
>
> **NAV-AP** tasks involved the change to autopilot or flight director mode from the Nav Select Menu page.
>
> **NAV-BP** tasks involved Bearing Pointers 1 and 2 changes from the Nav Select Menu and/or the Status page.
>
> **PFD** tasks involved configuration changes to the PFD from the PFD Menu page.
>
> **SFD** tasks involved configuration changes to the SFD from the SFD Menu page.
>
> **DIS CNTRL** tasks involved display configuration changes from the Display Control Menu page.

Table 7 depicts the experimental design that was used for the part-task. Design order was counterbalanced.

Table 8. Experimental Design

CONOP	DESIGN	WL/FIGP	DESIGN
Session 1	Session 2	Session 1	Session 2
48 trials	48 trials	48 trials	48 trials

Data Collection

The following data were recorded from the scripted role playing evaluation.

(1) Correct endstate: Defined as the proportion of tasks that were correctly completed according to task requirement

(2) Delta switch hits: Defined as the number of keystrokes which exceeded minimum keystroke requirements to correctly complete the task.

(3) Task completion time: Defined as the time duration in seconds from trial initiation until trial completion.

(4) Subjective questionnaires data. This consisted of a questionnaire given at the end of each design testing session (same questionnaire) and a final questionnaire consisting of direct design comparisons, safety and operational type questions.

(5) Subjective workload data. The SWORD (Vidulich, 1989) technique assesses workload by utilizing a series of pairwise comparisons between various combinations of configurations and functions. For the DAMU study, SWORD was used to provide relative judgments regarding "task difficulty" between three cockpit configurations and three tasks. The comparison cockpit

configurations were: CONOP Design, WL/FIGP Design and Baseline C-141. The tasks were defined along the lines of the DAMU pages and were the same as were used for the Nav Select functions in the performance measures (NAV-BP, NAV-REF, NAV-AP). All possible paired combinations of Designs and Task were listed for a total of 27 judgments.

Results

Performance Results

A repeated measures ANOVA was applied to the following dependent measures: correct endstate, delta switch hits and task completion time. The independent factors for all analyses were: DAMU design, task type and experience. Experience was defined as 2 levels. Level one used Block 1 data, which were the first 48 trials and Level two used Block 2 data which were the second 48 trials.

Correct Endstate

No main effects or significant interactions were found for designs, task type or experience. For both designs, over 97% of the task trials reached the correct endstate.

Delta Switch Hits

The results showed a significant interaction between design and task type, $F\ (5, 55) = 3.63$, $p < 0.05$). Post hoc analysis revealed that the source of this interaction was due to performance differences between the two designs with the NAV-AP and the NAV-BP tasks. The WL/FIGP design had significantly more switch hits with the NAV-BP task than the CONOP design, $F\ (1,11) = 15.50$, $p < 0.05$; while, the CONOP design had significantly more switch hits than the WL/FIGP design with the PFD task, $F\ (1,11) = 15.36$, $p < 0.05$. No other significant differences were found. Figure 18 illustrates this interaction.

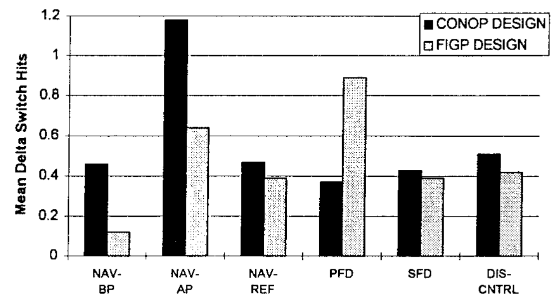

Figure 18. Task Type As A Function Of Delta Switch Hits.

The results also showed a main effect for experience and task type. For experience, results showed significantly more switch hits for the first block of trials than for the second block of trials across designs, $F\ (1, 11) = 11.49$, $p < 0.05$. For task type, the results showed significantly more switch hits for the NAV-AP task than for the other four tasks, $F\ (5, 55) = 4.45$, $p < 0.05$. All other effects, including design, were not significant.

Task Completion Time

As with delta switch hits, a significant interaction was found between design and task type, $F\ (5, 55) = 5.37$, $p < 0.05$. Also a main effect was found for experience, $F\ (1, 11) = 11.49$, $p < 0.05$ and task type, $F\ (5, 55) = 17.86$, $p < 0.05$. Post hoc analysis on the design by task type interaction revealed a similar pattern of results as the delta switch measure. For the CONOP design, results showed task completion time to be significantly longer with the NAV-BP task, $F\ (1, 11) = 16.59$, $p < 0.05$ as well as with the NAV-REF task, $F\ (1, 11) = 89.83$, $p < 0.05$. However, for the WL/FIGP design, task

completion time was significantly longer with the PFD tasks, $F(1, 11) = 5.82$, $p < 0.05$. See Figure 19.

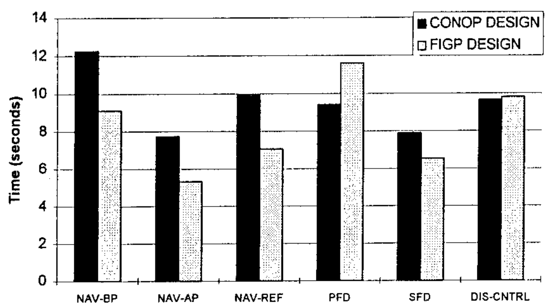

Figure 19 Type Task as a Function of Time.

The main effect for experience showed task completion time was significantly longer with the 1st block of trials.

Questionnaire Results

Frequencies were calculated for all questionnaire items employing rating scales. Complete responses to all questions, including comments, are provided in Appendix H. Significant findings of the questionnaire are summarized below.

The first part of the questionnaire addressed understandability and ease of use of the various menu pages, as well as overall operability and safety issues. Pilots were instructed to consider their operational experience as well as their part-task test experience when answering the questions. The following figures show the frequency distribution results for DAMU design comparisons with each of the primary menu pages.

Figure 20 shows that the majority of the subjects rated the Nav Select Menu as at least "moderately acceptable" with both designs. However, 3 subjects rated the CONOP design as borderline. Comments for both designs indicated that there were problems with: 1) implementation of the SKE option located on the AP/FD submenu and 2) confusion as to the submenu page (i.e., NAV or RADIO) on which a particular Bearing Pointer 1 option was located.

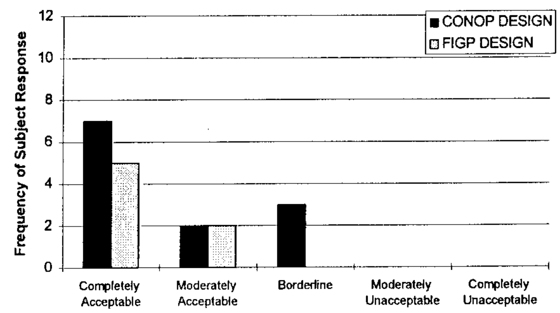

Figure 20. Understandability/ Ease of Use of the Nav Select Menu.

Figure 21 illustrates that most subjects rated the PFD Menu as at least "moderately acceptable" with both designs. Five subjects rated the CONOP design as "completely acceptable," and 8 subjects rated the WL/FIGP design as "completely acceptable."

Several pilots commented that the SYN MAG options (YES / NO) in the CONOP design is somewhat ambiguous. The YES / NO options could be mistaken for synthetic magnetic and magnetic rather than synthetic magnetic and true. In the WL/FIGP design, this same line item function was named HDG with the options of TRUE and MAG. Pilots felt that HDG more precisely defined the function provided, and its associated options.

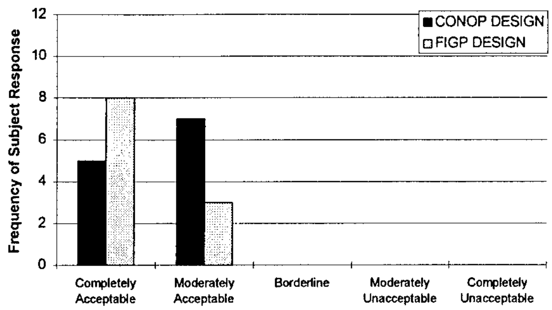

Figure 21. Understandability/Ease of Use of the PFD Menu.

Figure 22 illustrates that for both designs, the majority of the subjects rated the SFD Menu at least "moderately acceptable."

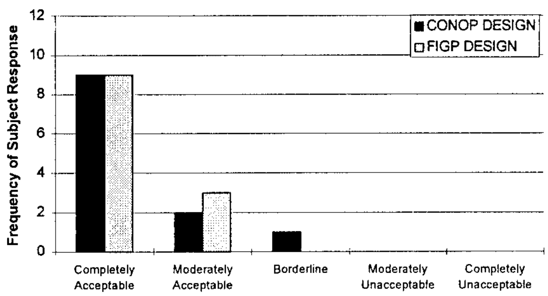

Figure 22. Understandability/Ease of Use of the SFD Menu.

Figure 23 illustrates that for both designs, the majority of the subjects rated the Display Control Menu at least "moderately acceptable." Two subjects rated the CONOP design as "borderline." All subject ratings for the WL/FIGP design were above "borderline".

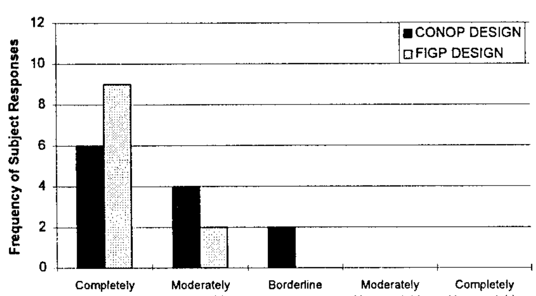

Figure 23. Understandability / Ease of Use Display Control Menu.

Figure 24 illustrates that although the majority of the subjects rated interpreting and implementing SKE-related options as at least "moderately acceptable" with both designs, 4 subjects rated SKE option use as "borderline" with the CONOP design and 1 subject rated it as "borderline" with the WL/FIGP design. For both DAMU designs, pilots suggested that SKE options on the AP/FD page should be NORM/SKE, instead of NO/YES. Other suggestions were to add TEST to the Zone Marker (ZM) options and to locate all SKE options on one page.

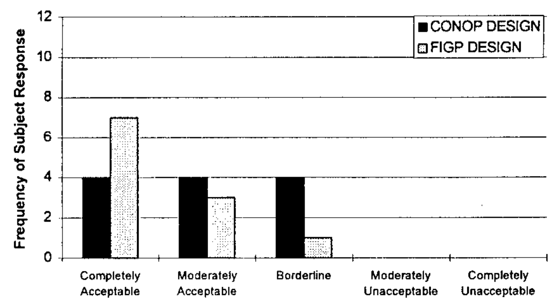

Figure 24. Interpreting and Implementing SKE-Related Options.

Figures 25 and 26 show frequency distributions of subject responses regarding questions that addressed operational or safety issues. Figure 25 shows the distribution of subject responses regarding the overall operational utility of the DAMU system. Although most subjects indicated that the operational utility of the DAMU was at least "moderately acceptable" for both designs, four subjects rated it as borderline with the CONOP design. Comments regarding these borderline ratings indicated that the menu structure was not intuitive.

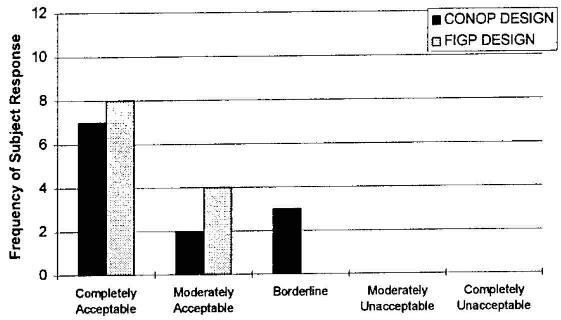

Figure 25. Overall Operational Utility of the DAMU.

Figure 26 shows the distribution of subject responses regarding safe flight operations utilizing the DAMU system. The majority of subject responses indicated "moderate agreement" with the statement that the DAMU system facilitates safe flight operations. However two subjects felt that the CONOP design did not facilitate safe operations and one subject responded this essentially way with the WL/FIGP design. With both designs, comments indicated that more time, effort and thought was required compared to the current system, especially with the Nav Select options.

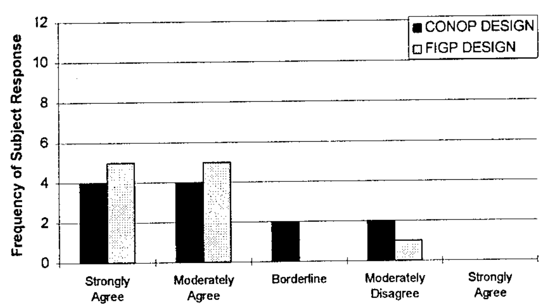

Figure 26. Responses to "The DAMU Design Facilitates Safe Flight Operations."

Figure 27 shows the distribution of subject responses regarding whether the DAMU system degrades their ability to perform associated tasks. The majority of subject reported that the DAMU system did not degrade task performance (NO response). With the CONOP design, two pilots indicated that performance was degraded because of the number of keystrokes that were needed to toggle through the menu structure. One of these two pilots indicated that performance would also be degraded with the WL/FIGP design but suggested that training should offset this effect.

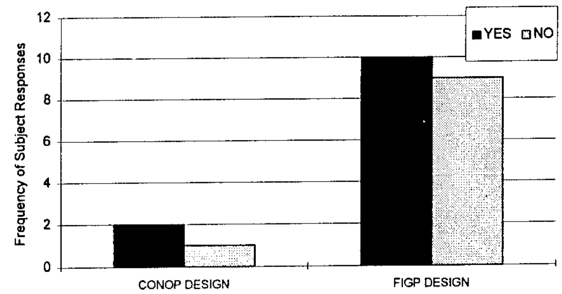

Figure 27. Responses to "Does the DAMU Degrade Your Ability To Perform Any Tasks?"

The second part of the questionnaire directly compared the two DAMU designs. Figure 28 illustrates overall comparison findings.

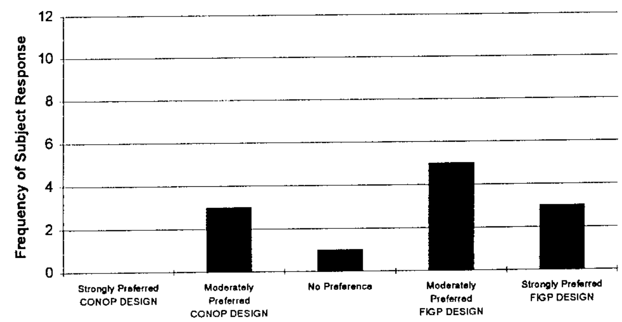

Figure 28. Comparison Between DAMU Designs.

As illustrated in Figure 28, of the twelve pilot subjects, eight moderately or strongly preferred the WL/FIGP design; whereas three moderately preferred the CONOP design.

Subjective Workload Dominance Results

SWORD data were analyzed using a 3 Design by 3 Task Repeated Measures ANOVA. The designs were: CONOP, WL/FIGP and baseline C-141. The tasks were: Nav-BP, Nav-AP, and Nav-REF, the same tasks that

were used for the Nav Select functions in the performance analysis. Figure 29 illustrates the main effect that was found for Design, $F(2, 22) = 21.07$, $p < 0.05$. No other significant differences were found.

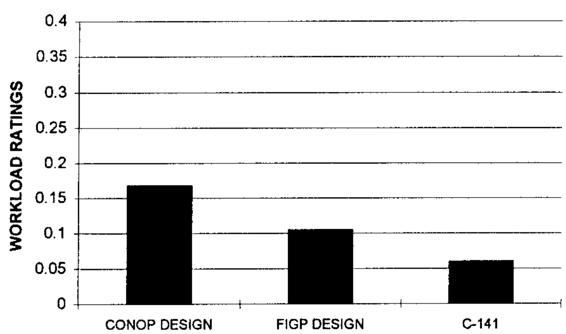

Figure 29. Design as a function of SWORD Ratings. Larger rating numbers indicate higher perceived workload.

Post hoc analysis using the Tukey HSD test revealed that the CONOP design had significantly higher subjective workload over the WL/FIGP or C-141 designs ($p < 0.05$). No other significant differences were found.

Discussion

Two display designs were investigated: 1) the DAMU design described in CONOP Rev B (referred to as the CONOP design, and (2) an alternative design developed by WL/FIGP (referred to as the WL/FIGP design). Specific test objectives were to evaluate the DAMU's ease of menu navigation and adequacy of menu functions. To accomplish these objectives, pilot performance and subjective data were collected to identify design deficiencies and to compare the two designs.

Overall, the results showed that both designs would be suitable for use in the C-141 aircraft with some minor modifications. The performance data showed that subjects (over 97%) successfully completed the assigned tasks with both designs. Also the subjective data showed that most pilots felt that both designs generally met operational requirements and were safe.

The results also suggested the need for design improvements. Strengths and weaknesses were found in both designs. For example, faster performance was found with the WL/FIGP design for tasks which required attitude or heading reference changes, and tasks which required changes to the autopilot/flight director modes. This finding may be due to basic menu navigation differences between the two designs. The WL/FIGP design had only one primary menu page (Nav Select) to make attitude/heading reference and AP/FD selections, whereas the CONOP design had two pages (Status, Nav Select) in which the same actions could be accomplished. The availability of two paths for performing the same functions may have resulted in some confusion as to where certain options were located in the menu structure.

More likely, the faster performance time with the WL/FIGP design resulted from the ability to quickly cycle through available options with repeated presses on the same key. With the CONOP design, attitude and heading reference options were displayed on the adjacent DAMU screen. This design required more visual searching and hand-travel distance than the WL/FIGP design, both of which can serve to increase task completion time.

The CONOP design led to faster performance for tasks which required configuring the PFD. This finding suggests that the rotary toggle design is best suited for those selections with familiar options. Since configuring the PFD was a new task to C-141 pilots (existing system is not configurable),

they were not familiar with available options. However, as the pilots become more experienced with the DAMU system, this effect should be mitigated or possibly reversed given the results obtained with the attitude/heading reference source tasks.

Although there was a high degree of consistency between delta switch hit and response time performance measures, the response time measure is more relevant to real-world requirements. The response time measure is an indication of the time it takes to complete a task, whereas the delta switch measure describes the process involved. In the DAMU system, it was found that in some cases, more switch hits did not necessarily result in longer response times. This is because rotary toggle switch hits can be made more quickly than going to another menu page to make the same number of or, in some instances, more keypresses.

In addition, the endstate performance measure did not detect differences between the designs. This is not unexpected, since an unlimited amount of time was given to the subjects to complete the tasks. In real-world conditions, however, time constraints will exist, particularly in time-stressed emergency conditions. Therefore, the endstate measure, as used in the current study, may not be as accurate as other measures (and subjective data) for predicting real-world performance and assessing design deficiencies.

Recommendations

Given the results, we recommend employing the WL/FIGP design with the following modifications:

- Highlight current option on the left DAMU screen.
- Group SKE options on one page.
- Add TEST to Zone Marker options.
- Put all Bearing Pointer 1 options on one page.
- More strongly annunciate control of other crew's DAMU.
- Annunciate when PFD/SFD are repeat displays.
- Indicate DAMU option unavailability.

Realizing that budgetary constraints may prohibit implementing the WL/FIGP design, the following are recommended improvements to the CONOP design. These improvements incorporate some preferred elements of the WL/FIGP design:

- Display status information on the Nav Select page.
- Implement rotary toggle of attitude/heading options on both the Nav Select and Status pages.
- Implement all of the above WL/FIGP design recommendation, except for highlighting.

PART-TASK EVALUATION EFFORT SUMMARY

The part-task simulations conclude the first of a two-phase evaluation effort. In this phase, we have drawn from a large pool of subject matter experts with operational and technical backgrounds to develop proposed design concepts for the PFD and DAMU components of the CDS. After assessing the designs through a limited analysis effort, we then began a building-block approach to their formal evaluation. The primary goal of the part-task studies was to verify the designs of individual CDS components. The

emphasis of these evaluations was on the suitability of the individual components, and their ability to provide an efficient crew-vehicle interface as stand-alone units.

The results from the studies have identified numerous improvements that are recommended for incorporation into the designs. Once incorporated, the component designs will have reached a relatively mature level of development, and will be ready for evaluation as an integrated system. The evaluation of the integrated system com prised the second phase (full mission simulation) of the two-part evaluation effort. It specifically addressed integration of the entire CDS system (PFD, SFD and DAMU), ability for the CDS system to support C-141 functions, and the acceptability of the integration of the CDS system into the current C-141 cockpit. The methods and results of the full mission evaluation are described in *Volume II: Full Mission Simulation* (Toms, Cone, Gier, Boucek, Brown, & Patzek, 1995).

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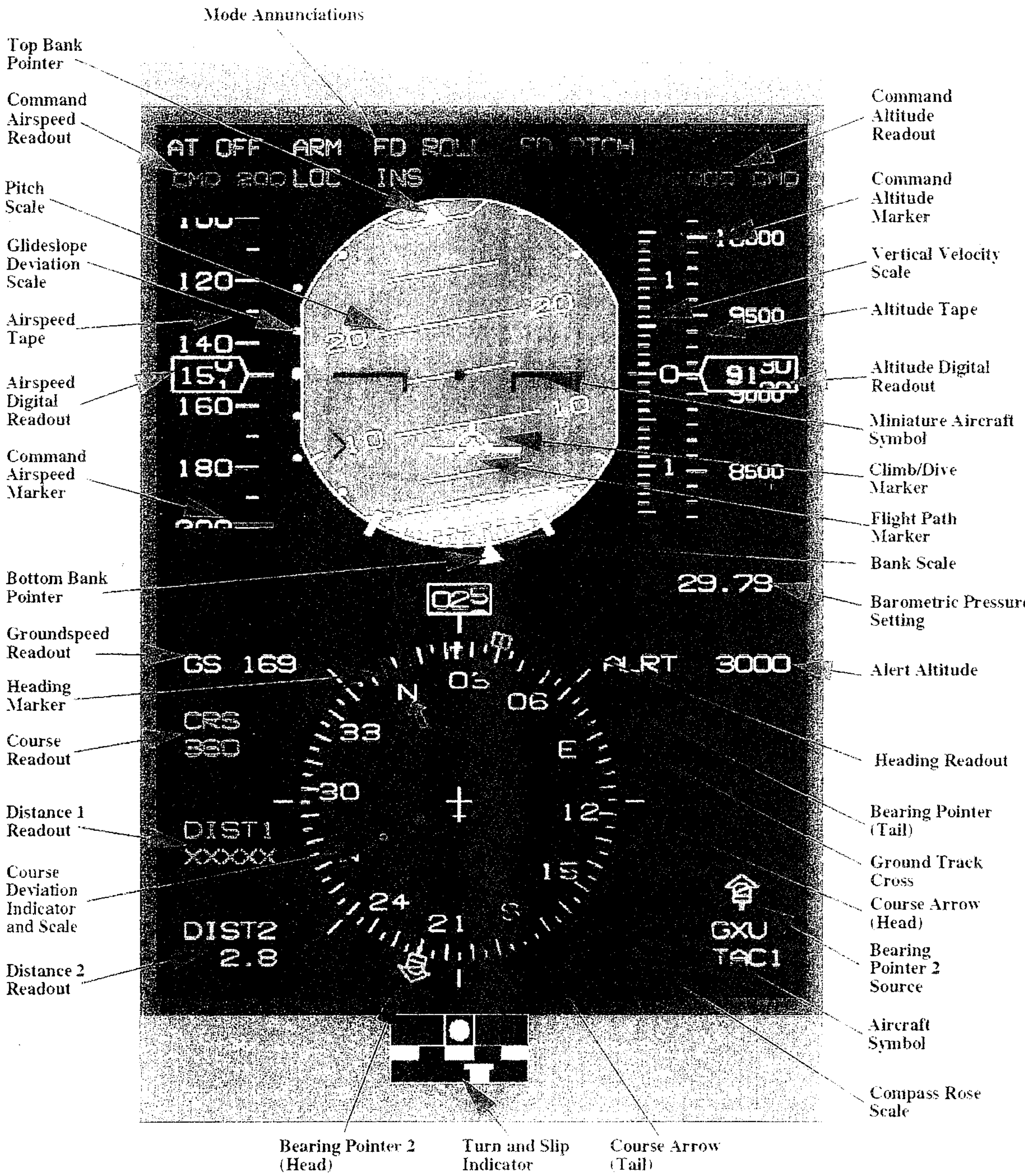
APPENDIX A

Functional Descriptions of Tested Primary Flight Display Formats



CDS Attitude Mode

CDS ATTITUDE MODE ADI ELEMENTS

ELEMENT	FUNCTIONALITY
CLIMB/DIVE MARKER	Displays the current climb-dive angle when read against the pitch scale. The climb-dive marker moves dynamically within the limits of the ADI instantaneous field of view. When the true climb-dive angle exceeds the ADI field of view, the climb-dive marker is limited at the edge of the ball, and flashes.
MINIATURE AIRCRAFT SYMBOL	The miniature aircraft symbol is the primary flight reference for the ADI. It is fixed in the center of the ADI ball and indicates aircraft pitch when read with respect to the pitch scale.
FLIGHT PATH MARKER	Indicates the actual flight path of the aircraft when read against the pitch scale.
PITCH SCALE	The pitch scale serves as the reference scale for the miniature aircraft symbol. It moves relative to the fixed miniature aircraft symbol. Pitch lines are presented every 2.5 degrees between -10 and +10 degrees, and every 5 degrees beyond that range. Total instantaneous field of view is 30 degrees.. When the true horizon representation exceeds the ADI field of view, the line becomes dashed, and remains in view to show the direction to the true horizon. When pitch exceeds -30 and +30 degrees, the ends of the pitch scale lines are angled 30 degrees away from the horizon.
AIRSPEED DEVIATION CUE	A segmented line that "grows" above or below the left wing of the miniature aircraft symbols to indicate deviation from commanded airspeed. (Not Shown)
BANK POINTERS AND SCALES	A moving pointer, fixed scale display that indicates aircraft bank angle. One is provided at the top and bottom of the ADI.
PITCH AND BANK STEERING BARS	Indicates the magnitude and direction of pitch and bank steering error when read against the miniature aircraft symbol. (Not Shown)
RISING RUNWAY	Displays localizer deviation and radar altitude during landing. The rising runway "grows" from the bottom of the ADI when the aircraft descends below 180 feet. It intersects with the miniature aircraft symbol at touchdown. (Not Shown)
VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION)	Presents aircraft displacement above or below an ILS glideslope on a five dot scale.
LOCALIZER DEVIATION INDICATOR	Indicates lateral deviation from the desired locailzer course during an ILS approach on a five dot scale. (Not Shown)
MODE ANNUNCIATIONS	Indicates what mode in being displayed on the ADI (i.e. SKE, ILS, etc.)
TURN AND SLIP INDICATOR	The needle and ball indicate rate of turn and slip/skid, respectively.
ACCELERATION CUE	Indicates acceleration and deceleration along the longitudinal axis of the aircraft.

CDS ATTITUDE MODE HSI ELEMENTS

ELEMENT	FUNCTIONALITY
COURSE ARROW	Shows pilots selected course and rotates with the compass card once selected.
COURSE DEVIATION INDICATOR AND SCALE	Displays direction and magnitude of deviation from the course.
TO-FROM INDICATOR	Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol. (Not Shown)
COMPASS ROSE SCALE	Shows a 360-degree scale (N=360, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading changes. Heading can be read against the upper lubber line and in a digital readout box. The scale readout can be set to MAG, TRU, or GRID mode, and can display either heading or groundtrack.
AIRCRAFT SYMBOL	A fixed symbol that represents ownship position with respect to the navigation situation.
HEADING MARKER	Provides a pilot selectable reference to the desired heading on the compass rose scale.
BEARING POINTERS	Indicates relative and magnetic bearing to the selected navigation aid. Two bearing pointers are provided on the outside portion of the compass rose.
COURSE READOUT	Provides a digital readout of the selected course.
DISTANCE READOUT	Indicates distance to the selected navigation aid to the nearest tenth of a mile and provides and indication that distance information is invalid. Two distance readouts are provided, one associated with each bearing pointer.
GROUND TRACK CROSS	Indicates ground track when the EHSI is in heading mode and is overlaid on the compass rose scale.
HEADING DIAMOND	Indicates heading when the EHSI is in track mode and is overlaid on the compass rose scale. (Not Shown)
BEARING POINTER SOURCES	Indicates source of bearing pointer information.

CDS ATTITUDE MODE AIRSPEED INDICATOR

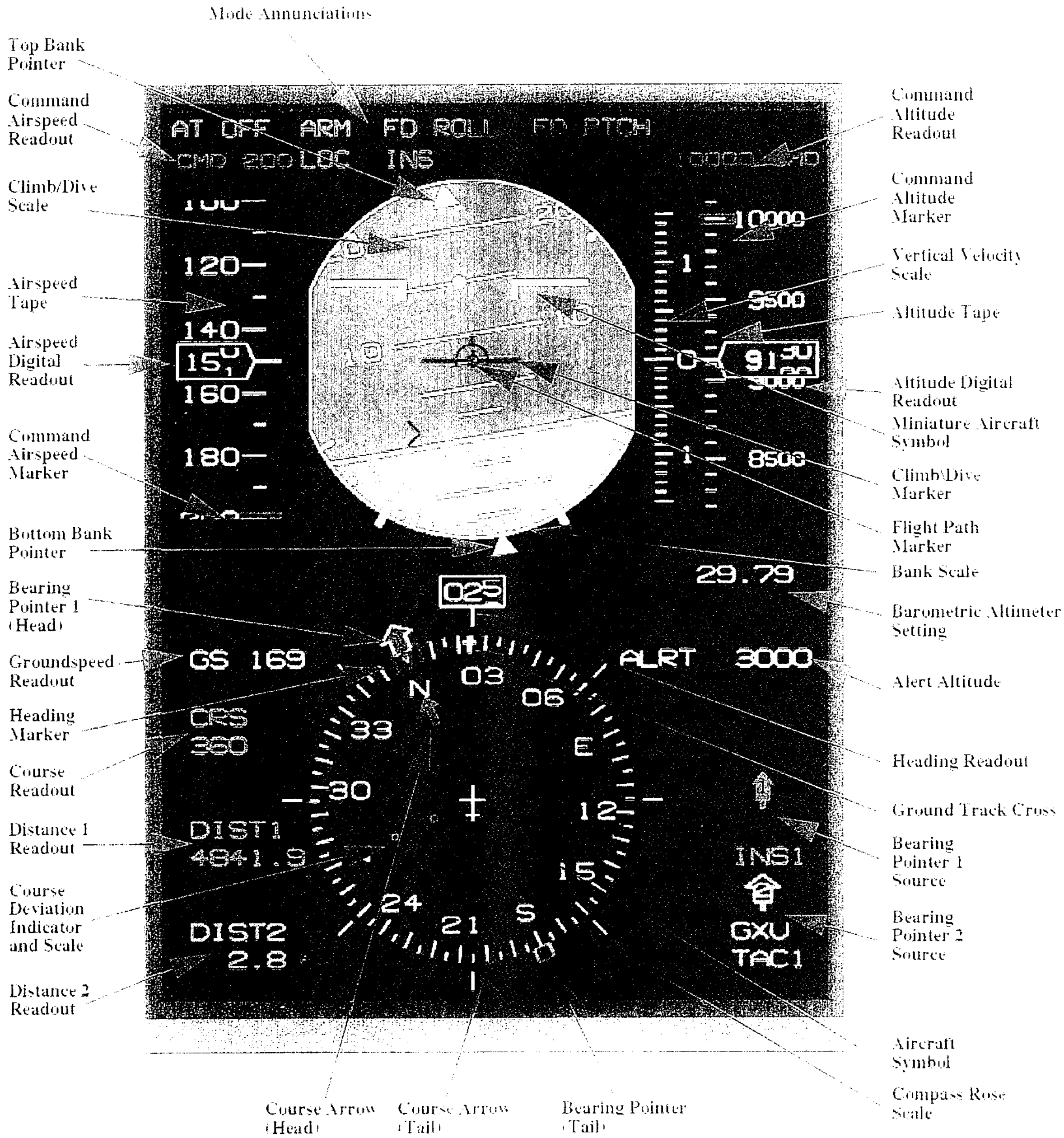
ELEMENT	FUNCTIONALITY
AIRSPEED TAPE	Provides a vertical tape display that moves in response to aircraft airspeed changes. Airspeed is read against a fixed reference line.
AIRSPEED DIGITAL READOUT	Provides a digital readout with a rolling counter type format of indicated airspeed
MACH INDICATOR	Provides a digital readout of true mach from 0.01 to 0.999 Mach in thousandthss of each mach increments. A warning is provided when the mach limit is being approached. Color coding is as follows: 1) when mach exceeds .78, the window and readout is displayed in yellow; 2) when mach exceeds .80, the window is displayed in red and the readout is displayed in yellow; and 3) when mach exceeds .825, both the window and the readout is displayed in red. The mach readout window is not displayed for mach values of .4 or less. (Not Shown)
GROUNDSPEED READOUT	Provides a digital readout of the groundspeed.
COMMAND AIRSPEED MARKER	Indicates commanded airspeed graphically on the airspeed tape. If the commanded airspeed value is not in view, the command marker will be positioned at the top or bottom of the airspeed tape.
COMMAND AIRSPEED READOUT	Provides a digital readout of the commanded airspeed.

CDS ATTITUDE MODE ALTITUDE INDICATOR

ELEMENT	FUNCTIONALITY
ALTITUDE TAPE	Provides a vertical tape display that moves in response to aircraft altitude changes. Altitude is read against a fixed reference line.
ALTITUDE DIGITAL READOUT	Provides a digital readout of indicated altitude in a rolling counter type format. When any digit changes at a rate of three digits per second, or faster, a zero replaces that digit
RADAR ALTITUDE DIGITAL READOUT	Provides a digital readout of the Above Ground Level (AGL) altitude. (Not Shown)
RADAR ALTITUDE THERMOMETER INDICATOR	Provides a thermometer ribbon that appears at the bottom of the altitude scale at 1000 ft. The difference between the top of the thermometer and the center reference line is the ground elevation. (Not Shown)
COMMAND ALTITUDE MARKER	Indicates commanded altitude graphically on the altitude tape. If the commanded altitude value is not in view, the command marker will be positioned at the top or bottom of the altitude tape.
COMMAND AIRSPEED READOUT	Provides a digital readout of the commanded altitude.
BAROMETRIC ALTIMETER SETTING	Provides a digital readout of the barometric altimeter setting.
ALERT ALTITUDE	Provides a digital readout of selected alert altitude.

CDS ATTITUDE MODE VERTICAL VELOCITY INDICATOR

ELEMENT	FUNCTIONALITY
VERTICAL VELOCITY SCALE	Indicates rate of climb or descent in feet per minute using a vertical fixed scale format. The vertical velocity is determined by reading the position of the thermometer indicator against the left side of the scale. The scale normally provides a total range of 3000. When vertical velocity exceeds 1500 fpm, a boxed digital readout is presented above the scale and the digital readout changes to show up to 9.9 (x 1000) fpm to the nearest 100 fpm.



CDS Climb-Dive Mode

CLIMB-DIVE MODE ADI ELEMENTS

ELEMENT	FUNCTIONALITY
CLIMB/DIVE MARKER	The climb-dive marker is the primary flight reference symbol for the ADI. It is fixed in the center of the ADI ball and indicates aircraft climb-dive angle when read with respect to the pitch scale.Displays the current climb-dive angle when read against the pitch scale. When the true pitch angle exceeds the ADI field of view, the climb-dive marker is limited at the edge of the ball, and flashes.
MINIATURE AIRCRAFT SYMBOL	Displays the current pitch angle when read against the pitch scale. The miniature aircraft symbol moves dynamically within the limits of the ADI instantaneous field of view, and limits at the edge of the display and flashes when the true climb-dive angle exceeds the ADI field of view.
FLIGHT PATH MARKER	Indicates the actual flight path of the aircraft when read against the pitch scale.
CLIMB/DIVE SCALE	The pitch scale serves as the reference scale for the miniature aircraft symbol. It moves relative to the fixed climb-dive angle symbol. Pitch lines are presented every 2.5 degrees between -10 and +10 degrees, and every 5 degrees beyond that range. Total instantaneous field of view is 30 degrees.. When the true horizon representation exceeds the ADI field of view, the line becomes dashed, but remains in view to show the direction to the true horizon. When pitch exceeds +/-30 degrees, the ends of the pitch scale lines are angled 30 degrees away from the horizon.
AIRSPEED DEVIATION CUE	A segmented line that "grows" above or below the left wing of the miniature aircraft symbols to indicate deviation from commanded airspeed. (Not Shown)
BANK POINTERS AND SCALES	A moving pointer, fixed scale display that indicates aircraft bank angle. One is provided at the top and bottom of the ADI.
PITCH AND BANK STEERING BARS	Indicates the magnitude and direction of pitch and bank steering error when read against the miniature aircraft symbol. (Not Shown)
RISING RUNWAY	Displays localizer deviation and radar altitude during landing. The rising runway "grows" from the bottom of the ADI when the aircraft descends below 180 feet. It intersects with the miniature aircraft symbol at touchdown. (Not Shown)
VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION)	Presents aircraft displacement above or below an ILS glideslope on a five dot scale. (Not Shown)
LOCALIZER DEVIATION INDICATOR	Indicates lateral deviation from the desired locailzer course during an ILS approach on a five dot scale. (Not Shown)
MODE ANNUNCIATIONS	Indicates what mode in being displayed on the ADI (i.e. SKE, ILS, etc.)
ACCELERATION CUE	Indicates acceleration and deceleration along the longitudinal axis of the aircraft.

CDS CLIMB-DIVE MODE HSI ELEMENTS

ELEMENT	FUNCTIONALITY
COURSE ARROW	Shows pilots selected course and rotates with the compass card once selected.
COURSE DEVIATION INDICATOR AND SCALE	Displays direction and magnitude of deviation from the course.
TO-FROM INDICATOR	Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol. (Not Shown)
COMPASS ROSE SCALE	A compass showing a 360-degree scale (N=360, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading changes. Heading can be read against the upper lubber line and in a digital readout box. The scale readout can be set to MAG, TRU, or GRID mode, and can display either heading or groundtrack.
AIRCRAFT SYMBOL	A fixed symbol that represents ownship position with respect to the navigation situation.
HEADING MARKER	Provides a reference to the desired heading on the compass rose scale.
BEARING POINTERS	Indicates relative and magnetic bearing to the selected navigation aid. Two bearing pointers are provided on the outside portion of the compass rose.
COURSE READOUT	Provides a digital readout of the selected course.
DISTANCE READOUT	Indicates distance to the selected navigation aid to the nearest tenth of a mile and provides and indication that distance information is invalid. Two distance readouts are provided, one associated with each bearing pointer.
GROUND TRACK CROSS	Indicates ground track when the EHSI is in heading mode and is overlaid on the compass rose scale.
HEADING DIAMOND	Indicates heading when the EHSI is in track mode and is overlaid on the compass rose scale. (Not Shown)

CDS CLIMB-DIVE MODE AIRSPEED INDICATOR

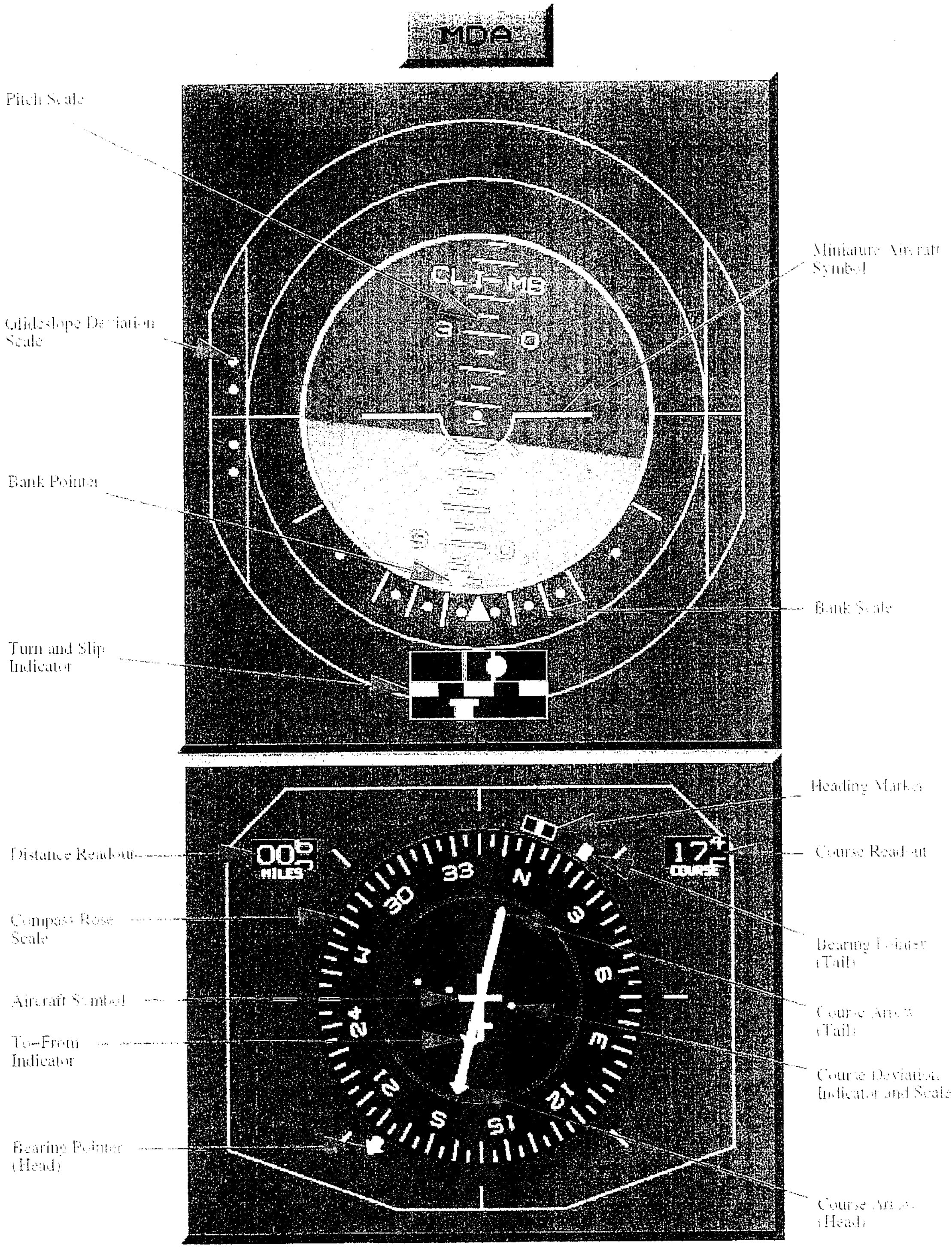
ELEMENT	FUNCTIONALITY
AIRSPEED TAPE	Provides a vertical tape display that moves in response to aircraft airspeed changes. Airspeed is read against a fixed reference line..
AIRSPEED DIGITAL READOUT	Provides a digital readout of indicated airspeed ina rolling counter type format.
MACH INDICATOR	Provides a digital readout of true mach from 0.01 to 0.999 Mach in thousandthss of each mach increments. A warning is provided when the mach limit is being approached. Color coding is as follows: 1) when mach exceeds .78, the window and readout is displayed in yellow; 2) when mach exceeds .80, the window is displayed in red and the readout is displayed in yellow; and 3) when mach exceeds .825, both the window and the readout is displayed in red. The mach readout window is not displayed for mach values of .4 or less. (Not Shown)
GROUNDSPEED READOUT	Provides a digital readout of the groundspeed.
COMMAND AIRSPEED MARKER	Indicates commanded airspeed graphically on the airspeed tape. If the commanded airspeed value is not in view, the command marker will be positioned at the top or bottom of the airspeed tape.
COMMAND AIRSPEED READOUT	Provides a digital readout of the commanded airspeed.

CDS CLIMB-DIVE MODE ALTITUDE INDICATOR

ELEMENT	FUNCTIONALITY
ALTITUDE TAPE	Provides a vertical tape that moves in response to aircraft altitude changes. Altitude is read against a fixed reference line.
ALTITUDE DIGITAL READOUT	Provides a digital readout of indicated airsped in a rolling counter type. When any digit changes at a rate if three digits per second, or faster, a zero replaces that digit
RADAR ALTITUDE DIGITAL READOUT	Provides a digital readout of the Above Ground Level (AGL) altitude. (Not Shown)
RADAR ALTITUDE THERMOMETER INDICATOR	Provides a thermometer ribbon that appears at the bottom of the altitude scale at 1000 ft. The difference between the top of the thermometer and the center reference line is the ground elevation. (Not Shown)
COMMAND ALTITUDE MARKER	Indicates commanded altitude graphically on the altitude tape. If the commanded altitude value is not in view, the command marker will be positioned at the top or bottom of the altitude tape.
COMMAND AIRSPEED READOUT	Provides a digital readout of the commanded altitude.
BAROMETRIC ALTIMETER SETTING	Provides a digital readout of the barometric altimeter setting.
ALERT ALTITUDE	Provides a digital readout of selected alert altitude.

CDS CLIMB-DIVE MODE VERTICAL VELOCITY INDICATOR

ELEMENT	FUNCTIONALITY
VERTICAL VELOCITY SCALE	Indicates rate of climb or descent in feet per minute using a vertical fixed scale format. The vertical velocity is determined by reading the position of the thermometer indicator against the left side of the scale. The scale normally provides a total range of 3000. When vertical velocity exceeds 1500 fpm, a boxed digital readout is presented above the scale and the digital readout changes to show up to 9.9 (x 1000) fpm to the nearest 100 fpm.



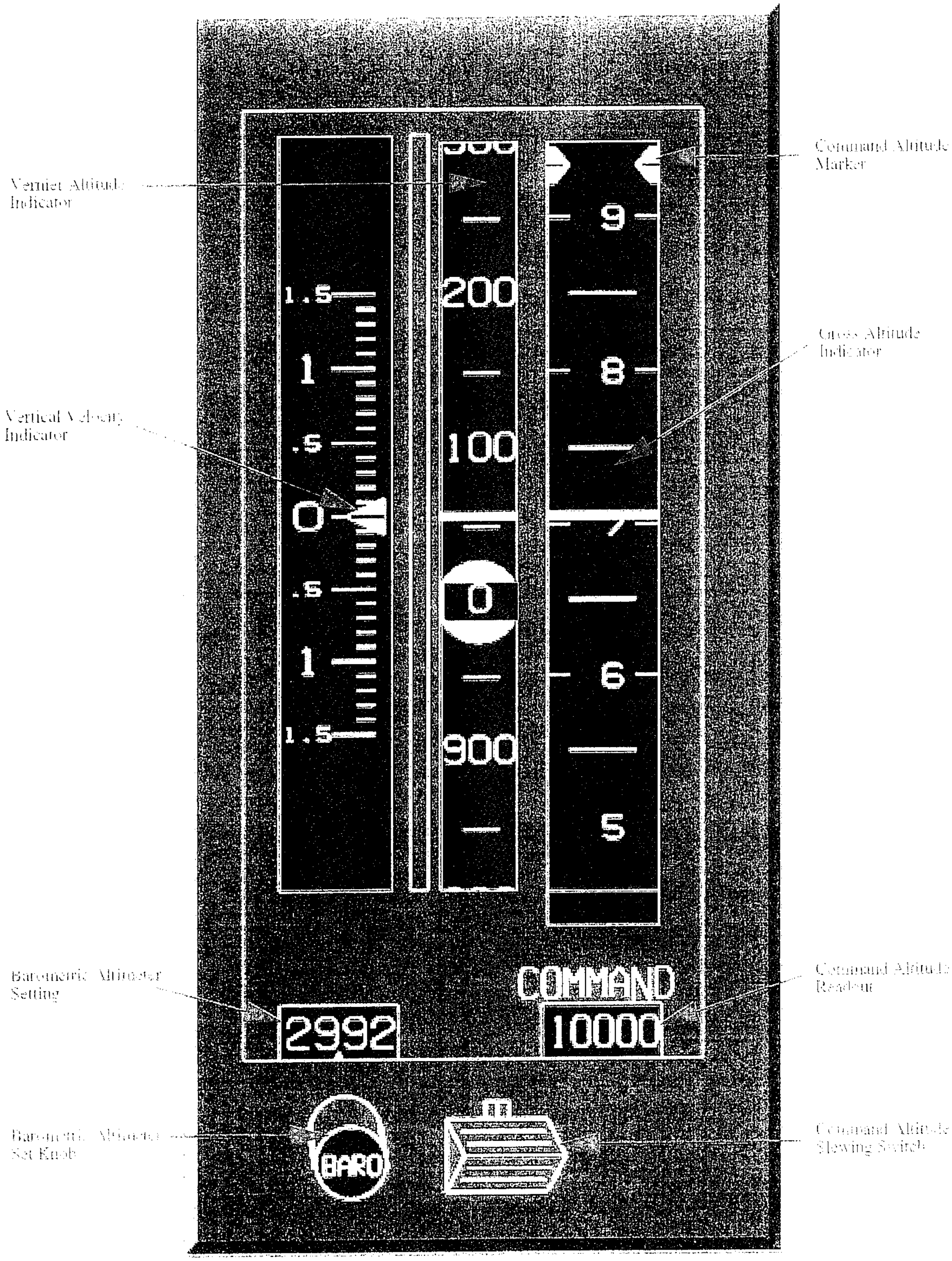
C-141 Electromechanical ADI and HSI

C-141 ADI ELEMENTS

ELEMENT	FUNCTIONALITY
MINIATURE AIRCRAFT SYMBOL	The primary flight control reference for the ADI. It is fixed in the center of the ADI ball and indicates aircraft pitch when read with respect to the pitch scale.
PITCH AND BANK STEERING BARS	Indicate the magnitude and direction of pitch and bank steering error when read against the miniature aircraft symbol. (Not Shown)
BANK POINTERS AND SCALES	A moving pointer, fixed scale display that indicates aircraft bank angle. One is provided at the top and bottom of the ADI. Utilizes five-degree increments to measure up to 60 degrees of bank angle
PITCH SCALE	The pitch scale serves as the reference scale for the miniature aircraft symbol. It is positioned on the ADI sphere and moves with respect to the miniature aircraft symbol. Scale lines are provided every 5 degrees but are labeled every 10 degrees. Total instantaneous field of view is approximately 90 degrees.
TURN AND SLIP INDICATOR	The needle and ball indicate rate of turn and slip/skid, respectively.
VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION)	Presents aircraft displacement above or below an ILS glideslope.

C-141 HSI ELEMENTS

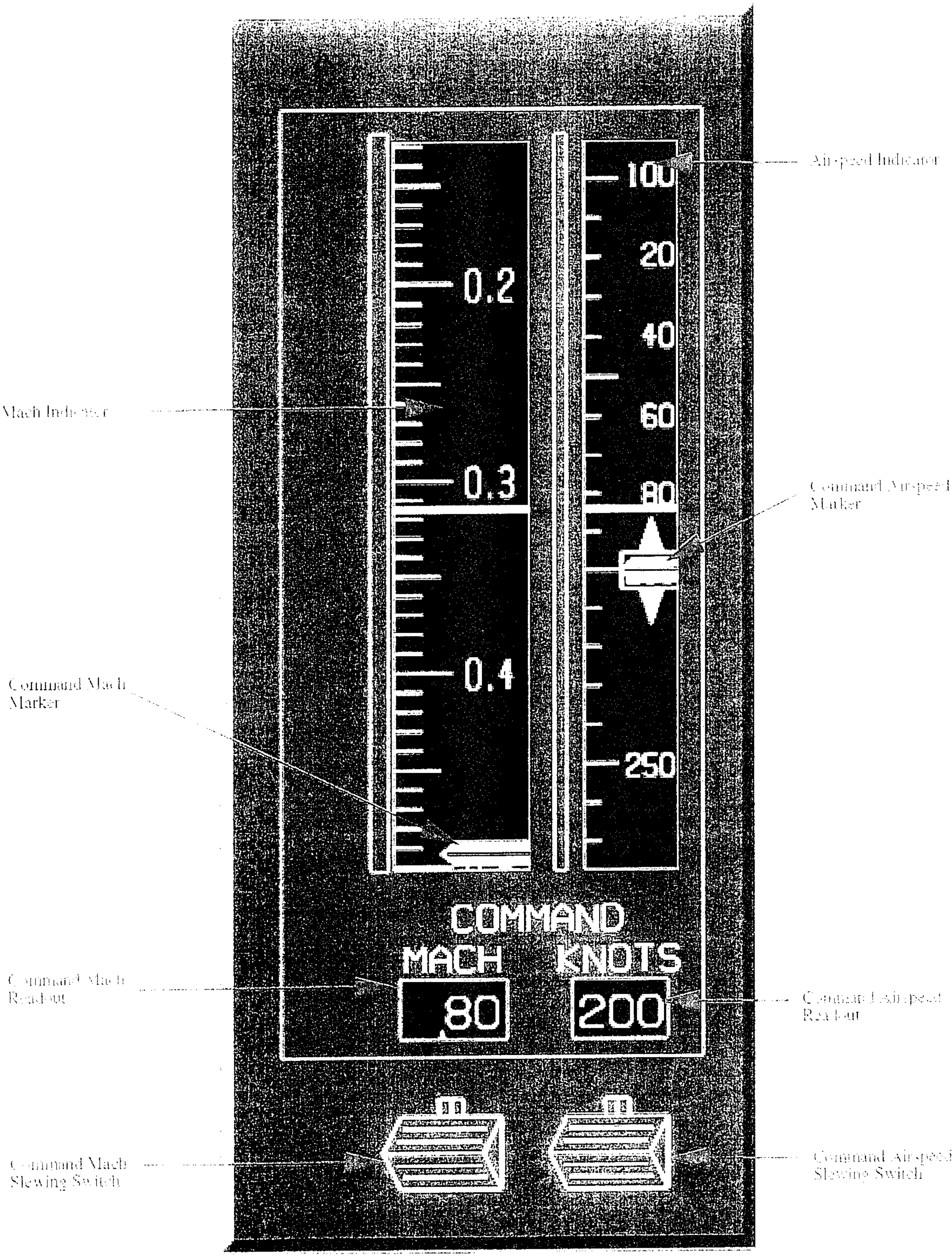
ELEMENT	FUNCTIONALITY
HEADING MARKER	Provides a reference to the desired heading on the compass rose scale.
COMPASS ROSE SCALE	A compass showing a 360-degree scale (N=360, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading changes. Heading can be read against the upper lubber line.
COURSE READOUT	Provides a rolling drum presentation of the pilot-selected course.
AIRCRAFT SYMBOL	A fixed symbol that represents the ownship position with respect to the navigation situation.
COURSE ARROW	Shows the pilot-selected course against the compass rose scale. Once set, it rotates with the compass card in response to aircraft heading changes.
COURSE DEVIATION INDICATOR AND SCALE	Displays direction and magnitude of deviation from the course on a 5 dot scale
BEARING POINTER	Indicates relative and magnetic bearing to the selected navigation aid.
DISTANCE READOUT	Rolling drum digital presentation displaying distance to the TACAN station when either INS or TACAN is selected.
TO-FROM INDICATOR	Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol.



C-141 Electromechanical Altitude Indicator

C-141 ALTITUDE INDICATOR

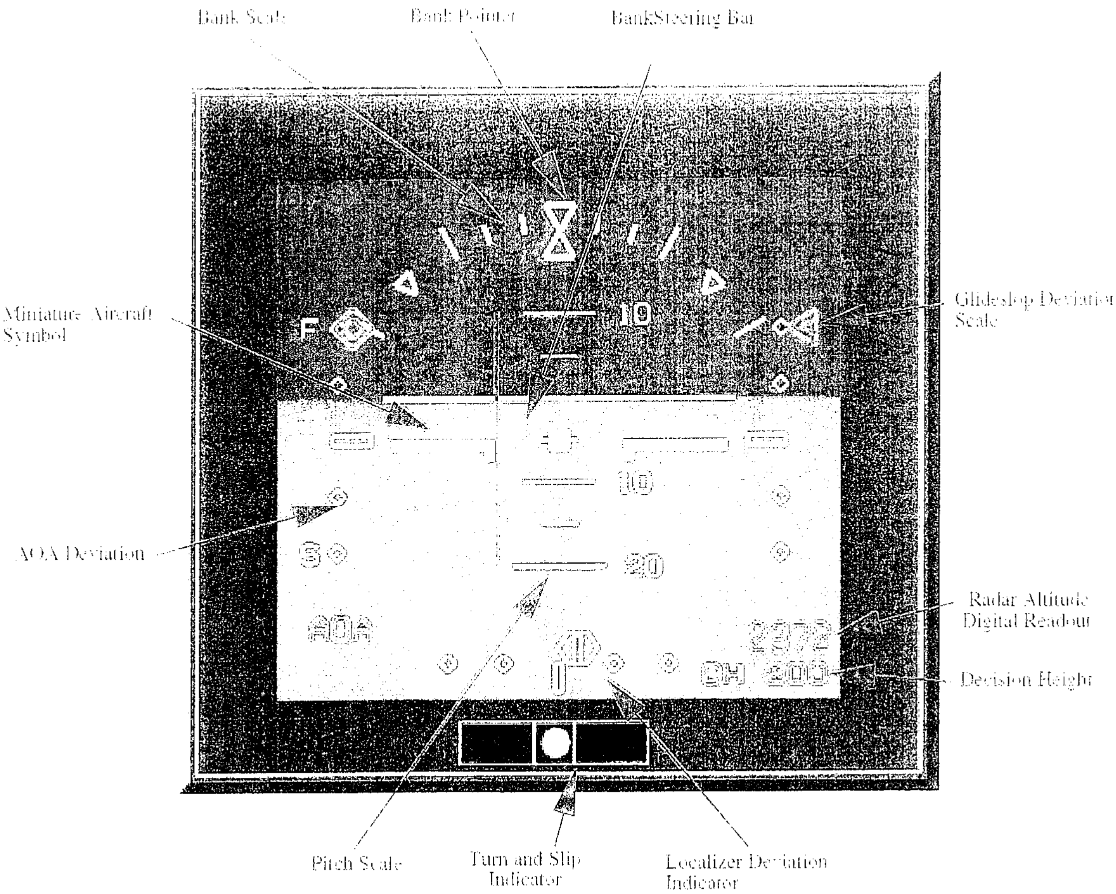
ELEMENT	FUNCTIONALITY
VERTICAL VELOCITY INDICATOR	Uses a moving pointer fixed scale format to display rate of climb or descent in feet per minute. The scale shows a total range of 3000 feet per minute. When the vertical velocity exceeds +/- 1500 fpm, digital readouts at the top or bottom of the VVI display fpm 100 fpm increments.
VERNIER ALTITUDE INDICATOR	Provides a vertical tape display that moves in response to aircraft changes in altitude. The scale is labeled in 100 feet increments with graduation marks every 50 feet. The vernier and gross altitude scales must both be read to determine specific aircraft altitude. Both are read against a fixed reference line. The vernier scale is primarily used to obtain trend and precise altitude information.
GROSS COMMAND ALTITUDE INDICATOR	Indicates current altitude on a vertical moving scale. The scale is labeled in thousands of feet, ranges from -1000 feet to +60,000 feet, and provides graduation marks every 500 feet. The scale is intended to provide a gross indication of altitude rather than trend and precise altitude information. It is intended to be used in conjunction with the vernier altitude scale.
BAROMETRIC ALTIMETER SETTING	Rolling drum digital presentation that indicates the barometric pressure setting.
COMMAND ALTITUDE MARKER	A short horizontal bar that is positioned on the vernier and gross altitude scales over the value set in the command altitude readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the instrument.
COMMAND ALTITUDE READOUT	Rolling drum format presentation of the commanded altitude.
BAROMETRIC ALTIMETER SETTING KNOB	Control used to set the barometric pressure setting.
COMMAND ALTITUDE SLEWING SWITCH	Control used to set the command altitude.



C-141 Electromechanical Mach Airspeed Indicator

C-141 MACH AIRSPEED INDICATOR

ELEMENT	FUNCTIONALITY
MACH INDICATOR	Vertical tape format that moves in response to aircraft changes in mach. The scale displays mach from 0.2 to 1.0 Mach in hundredths of each mach increments. Each one-tenth mach is numbered.
COMMAND MACH MARKER	A short horizontal bar that is positioned on the Mach scale over the value set in the command Mach readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the scale, as appropriate.
COMMAND MACH SLEWING SWITCH	Control used to set the command mach marker.
COMMAND MACH READOUT	Rolling drum presentation of commanded Mach setting.
AIRSPEED INDICATOR	Provides a vertical tape display that moves in response to aircraft airspeed changes. Airspeed is read against a fixed index line.
COMMAND AIRSPEED MARKER	A short horizontal bar that is positioned on the airspeed scale over the value set in the commanded airspeed readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the scale, as appropriate.
COMMAND AIRSPEED SLEWING SWITCH	Control used to set the command airspeed.
COMMAND AIRSPEED READOUT	Rolling drum presentation of the commanded airspeed.

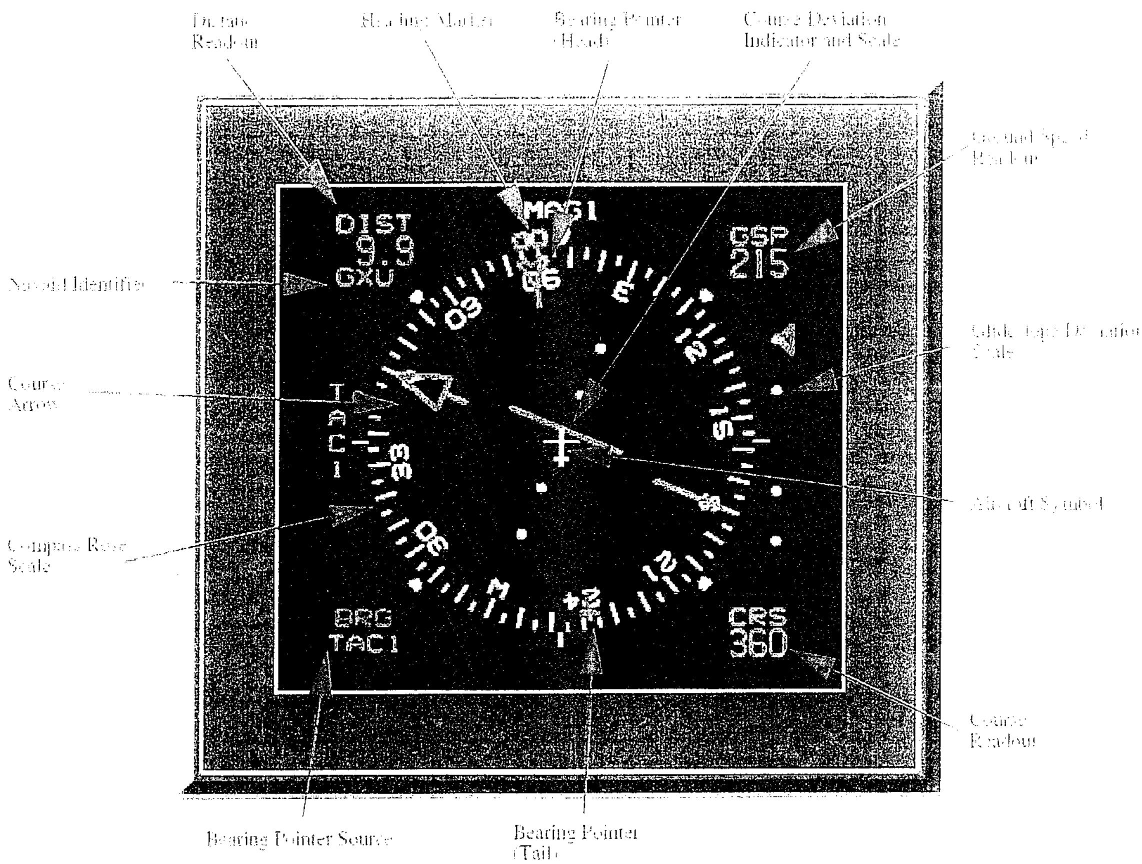


Bank Scale
Bank Pointer
BankSteering Bar
Miniature Aircraft Symbol
Glideslop Deviation Scale
AOA Deviation
Radar Altitude Digital Readout
Decision Height
Pitch Scale
Turn and Slip Indicator
Localizer Deviation Indicator
10
20
AOA
DH

T-1 ADI

T-1 ADI ELEMENTS

ELEMENT	FUNCTIONALITY
MINIATURE AIRCRAFT SYMBOL	The miniature aircraft symbol is the primary flight control reference for the ADI. It is fixed in the center of the ADI and indicates aircraft pitch when read with respect to the pitch scale.
BANK POINTERS AND SCALE	A moving pointer, fixed scale display that indicates aircraft bank angle. A single bank indicator is provided at the top of the ADI display.
PITCH REFERENCE SCALE	The pitch scale serves as the reference scale fo the miniature aircraft symbol. It moves relative to the fixed miniature aircraft symbol to show aircraft pitch. Pitch lines are provided every 5 degrees, providing a total field of view of approximately 45 degrees. The contrast between the blue sky and brown ground portions of the ADI serves as a "ghost horizon" when the real horizon is outside of the display field of view. A portion of the blue or brown always remains within the field of view to show direction to the horizon. Large arrows pointing toward the horizon are provided above +/- 30 degrees pitch.
TURN AND SLIP INDICATOR	The needle and ball indicate aircraft rate of turn and slip/skid, respectively.
VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION)	Presents aircraft displacement above or below an ILS glideslope.
AOA DEVIATION	A moving pointer, fixed scale presentation that shows deviation from optimal angle of attack for a 2.5 degree approach.
PITCH AND BANK STEERING BARS	Indicate the magnitude and direction of pitch and bank steering error when read against the miniature aircraft symbol. (Only Bank Steering Bar Shown)
RADAR ALTITUDE DIGITAL READOUT	Provides a digital readout of the Above Ground Level (AGL) altitude.
DECISION HEIGHT	Provides a digital readout of decision height.
LOCALIZER DEVIATION INDICATOR	Indicates lateral deviation from the desired course on a five dot scale.

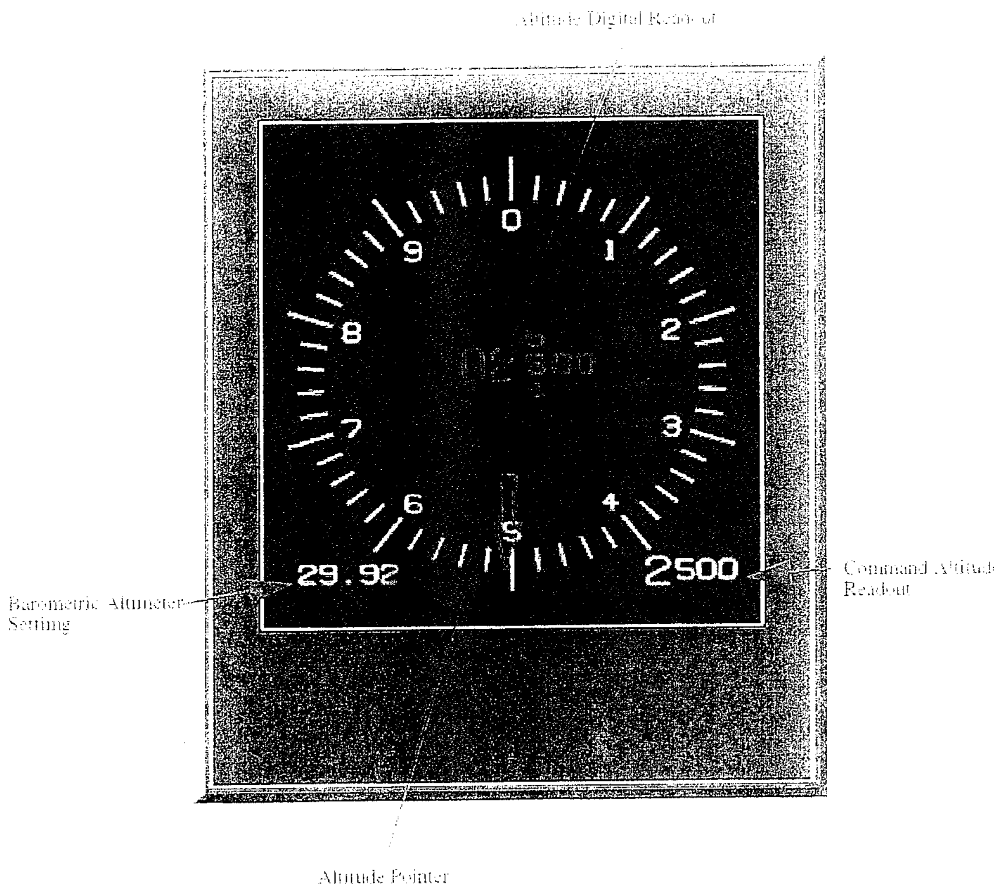


Course Deviation Indicator and Scale
DIST
9.9
GXU
MAG1
GSP
215
TAC1
BRG
TAC1
CRS
360
Bearing Pointer Source
Bearing Pointer
(Tail)

T-1 HSI

T-1 HSI ELEMENTS

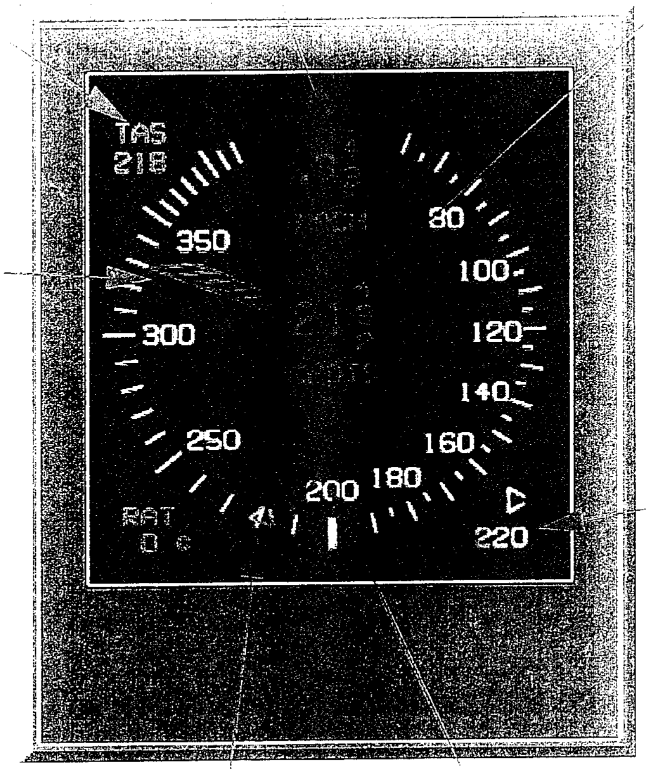
ELEMENT	FUNCTIONALITY
HEADING MARKER	Provides a reference to the pilot-selected heading on the compass rose scale.
COMPASS ROSE SCALE	A compass rose showing a 360-degree scale (N=360, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading.
ACTIVE COURSE DIGITAL READOUT	Provides a digital readout indicating the pilot-selected course.
AIRCRAFT SYMBOL	A fixed symbol that represents the ownship with respect to the navigation situation.
COURSE ARROW	Indicates selected course when read against the compass rose. Once set, it rotates with the compass card in response to aircraft heading changes.
COURSE DEVIATION INDICATOR AND SCALE	Displays direction and magnitude of deviation from the course on a five dot scale
VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION)	Displays vertical direction and magnitude of deviation from the glideslope on a five dot scale
BEARING POINTER	Indicates relative bearing to the selected navigation aids.
RANGE INDICATOR	Rolling drum presentation of distance to the TACAN station or next waypoint when either INS or TACAN is selected.
TO-FROM INDICATOR	Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol. (Not Shown)
GROUNDSPEED READOUT	Provides a digital readout of the groundspeed.
DISTANCE READOUT	Indicates distance to the selected navigation aid to the nearest tenth of a mile and provides and indication that distance information is invalid. One distance readout is provided and is associated with a bearing pointer.
NAVAID IDENTIFIER	Indicates chosen NAVAID source.



T-1 Altitude Indicator

T-1 ALTITUDE INDICATOR

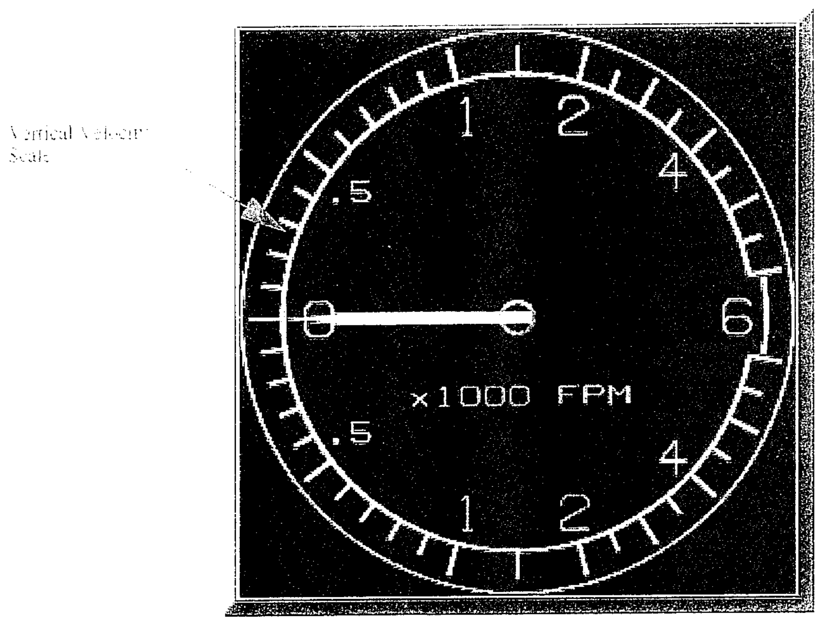
ELEMENT	FUNCTIONALITY
ALTITUDE INDICATOR	A moving pointer, round dial presentation of altitude. The scale is labeled in 100 foot increments and shows a total range of 1000 feet. It is intended to provide trend and precision, and must be used in conjunction with the digital readout.
ALTITUDE DIGITAL READOUT	Provides a digital readout of indicated aaltitude in a rolling drum type format.
BAROMETRIC PRESSURE READOUT	Rolling drum format indicating the barometric pressure setting.
COMMAND ALTITUDE CARET	Shows commanded altitude when read against the altitude scale. (Not Shown)
COMMAND ALTITUDE READOUT	Digital presentation indicating the commanded altitude.



T-1 Mach Airspeed Indicator

T-1 MACH AIRSPEED INDICATOR

ELEMENT	FUNCTIONALITY
MACH INDICATOR	Displays true mach from 0.01 to 0.99 Mach in hundredths of mach increments in a rolling drum format. Each one-tenth mach is numbered.
AIRSPEED INDICATOR	A moving pointer, round dial display of airspeed. The scale labeling is non linear and ranges from 0 through 420 knots.
AIRSPEED DIGITAL READOUT	Provides a digital readout of indicated airspeed in rolling drum format.
COMMAND AIRSPEED READOUT	Digital readout indicating the commanded airspeed
COMMAND AIRSPEED MARKER	Caret that indicates commanded airspeed when read against the airspeed scale.
RAW AIRSPEED TEMPERATURE READOUT	Provides a digital readout of raw airspeed temperature
TRUE AIRSPEED READOUT	Provides a digital readout of true airspeed.
MAXIMUM AIRSPEED INDICATOR	A pointer read against a digital readout that presents maximum aircraft airspeed.



T-1 Vertical Velocity Indicator

T-1 VERTICAL VELOCITY INDICATOR

DEVICE	FUNCTIONALITY
VERTICAL VELOCITY SCALE	A moving pointer, fixed circular scale presentation of vertical velocity. The scale labeling is nonlinear and shows a range of +/- 6000 feet per minute.

APPENDIX B

Primary Flight Display Evaluation Questionnaires

C-141 Primary Flight Display Questionnaire

Instructions: The following questions ask you to evaluate the primary flight displays you have used through rating scales and subjective comments. Base your responses on the tasks you flew in the simulator as well as on your operational experience. For each question, enter your rating in the blank or place a mark next to the desired answer, as appropriate. We also encourage you to write comments where space is provided. These comments are very important for the interpretation of the data, and will aid us in diagnosing specific design deficiencies and identifying good design features. If you have questions, please ask the test engineer.

The questionnaires will be broken into two parts. The first part will focus on one of the four designs you experience during the simulation. These will be filled out immediately after each session is completed. The second part will focus on comparing the four formats and other aspects of the simulation. It will be completed at the conclusion of all data collection sessions.

BIOGRAPHICAL DATA

Name:____

_

Rank (circle one): 0-1 0-2 0-3 0-4 0-5 0-6

Organization:____

—

Duty Station:_____________________________________**Duty**
Phone:____________________

Handedness: _____Left _____Right

Crew Qualification:
_____ Copilot
_____ First Pilot
_____ Aircraft Commander
_____ Instructor Pilot
_____ Evaluator Pilot
_____ Other (Specify)____________________________________

Special Qualifications: (e.g. in-flight refueling, NVG, Air-drop, Formation, SKE, LAPES, experience with electronic displays, etc.)

____

_

____

_

____

_

Please list military and civilian transport aircraft flown and approximate number of hours in each, beginning with the most recent.

Aircraft	Hours	Highest Crew Qualifaction

Date of Last Flight: __________________

C-141 Primary Flight Display Questionnaire - Part 1

Format: CONOP Attitude Mode **Subject Number:**_____________ **Date:**_____________

Instructions. This section focuses on symbology design and mechanization for the CONOP attitude mode format. You will first be asked to evaluate various components of the format, and then to evaluate the format as a whole. Rate each item using the scale below by entering the appropriate letter in each blank. Please provide comments for any item rated as "borderline" or worse. Base your responses on your operational experience, and your participation in the simulation evaluation tasks (UARs, ILS approaches, PICT tasks, and mission demonstrations).

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

ADI

Comments:

_____ 1. Size of the ADI ball

_____ 2. Contrast between symbols and sky on the ADI ball

_____ 3. Contrast between symbols and ground on the ADI ball

_____ **4. Pitch ladder design (scale, labels, etc)**

_____ 5. Bendy bar design

_____ **6. Level of Precision of Attitude Information**

_____ **7. Pitch symbol design**

_____ **8. Climb Dive marker design / mechanization**

_____ **9. Flight path marker design / mechanization**

_____ 10. Speed Worm Design / Mechanization

_____ 11. Acceleration Cue Design / Mechanization

_____ 12. Ghost horizon Design / Mechanization

_____ 13. Pitch and Bank Steering Bar Design / Mechanization

_____ 14. Rising Runway Design / Mechanization

_____ 15. Bank Pointer Design / Mechanization

_____ 16. Bank Scale Design

_____ 17. Bank Scale Precision

_____ **18. Integration of symbols presented on the ADI**

_____ **19. Color Usage on the ADI**

_____ **20. Level of Clutter on ADI**

_____ **21. Ease of interpreting flight path**

_____ **22. Ease of interpreting climb-dive angle**

_____ **23. Color of climb-dive marker (white)**

ADI (Continued)

Comments:

_____ **24. Color of pitch marker (black)**

_____ **23. Ease of Interpretating attitude information**

_____ **24. Overall ADI Design / Mechanization**

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the ADI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Airspeed Indicator

Comments:

_____ 1. Displayed range of the airspeed scale.

_____ 2. Commanded Airspeed Presentation (digital and bar)

_____ 3. Airspeed scale design (tics, labels, etc)

_____ 4. Precision of airspeed indicator

_____ 5. Design and mechanization of the digital readout

_____ 6. Presentation and placement of mach information

_____ 7. Quality of airspeed trend information provided

_____ 8. Presentation and placement of ground speed

_____ 9. Integration of airspeed scale components

_____ 10. Ability to quickly determine airspeed

_____ 11. Overall design and mechanization of airspeed indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the airspeed presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Altitude Indicator

Comments:

_____ 1. Displayed range of the altitude scale
_____ 2. Quality of barometric altimeter trend information
_____ 3. Altimeter scale design (tics, labels, etc)
_____ 4. Precision of barometric altimeter
_____ 5. Design and mechanization of the digital altitude readout
_____ 6. Commanded altitude presentation (digital and bar)
_____ 7. Presentation of digital radar altitude information
_____ 8. Design and mechanization of radar altitude "thermometer" indicator
_____ 9. Quality of radar altitude trend information
_____ 10. Range of radar altitude presentation
_____ 11. Presentation and placement of alert altitude readout
_____ 12. Presentation and placement of barometric altitude setting
_____ 13. Ability to quickly determine altitude
_____ 14. Overall design and mechanization of altitude indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the altitude presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Horizontal Situation Indicator

Comments:

_____ 1. Size of the HSI

_____ 2. Integration of navigation and heading information

_____ 3. HSI Scale design (tics, labels, etc)

_____ 4. Precision of heading / track information

_____ 5. Design and mechanization of the to-from indicator

_____ 5. Design and mechanization of the heading marker

_____ 6. Design and mechanization of the track cross

_____ 7. Design and mechanization of the heading diamond

_____ 8. Design and mechanization of the digital heading/track readout

_____ 9. Color coding usage

_____ 10. Design and mechanization of course arrow and CDI

_____ 11. Aircraft symbol design

_____ 12. Digital Presentation of course readout

_____ 13. Bearing pointer 1 design/mechanization

_____ 14. Bearing pointer 2 design/mechanization

_____ 15. Presentation of bearing pointer identification information

_____ 16. Presentation and placement of distance

_____ 17. HSI mode annunciations (TRU, TRK)

_____ 18. Ease of interpreting navigation information

_____ 19. Overall design and mechanization of the HSI

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the HSI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Vertical Velocity Indicator

Comments:

_____ 1. Quality of vertical velocity trend information

_____ 2. Displayed range of VVI scale

_____ 3. VVI scale design (tics, labels, etc)

_____ 4. Precision of vertical velocity information

_____ 5. Design / Mechanization of digital readout boxes

_____ 6. Design and mechanization of thermometer indicator

_____ 7. Ease of interpreting vertical velocity

_____ 8. Overall design and mechanization of vertical velocity indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the VVI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space:

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Overall CONOP Attitude Format

Comments:

_____ **1. Arrangement of primary flight display elements**

(HSI, Altimeter, Airspeed Scale, VVI, ADI ball)

_____ **2. Integration of primary flight display elements**

_____ **3. Contrast between symbols and background**

_____ **4. Discriminability of individual symbols**

_____ **5. Size of numeric labels**

_____ **6. Ability to perform an efficient crosscheck with the PFD**

_____ **7. Overall level of clutter on the PFD**

_____ **8. Color usage on the PFD**

_____ **9. Suitability for use as a C-141 primary flight reference**

_____ **10. Overall ease of interpretation of flight and navigation information**

_____ **11. Overall Design and mechanization**

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the overall PFD design, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

CONOP Attitude Mode Format

1. Were you able to quickly determine your attitude during the UARs?

_____Yes   _____No

Comments:

2. Were you able to quickly determine the correct control input during the UARs?

_____Yes   _____No

Comments:

3. Does this format provide adequate information for performing the PICT and ILS tasks?

_____Yes   _____No

Comments:

4. Rate your workload while performing the following tasks with the CONOP Attitude Mode format by placing a mark in the appropriate box for each task:

Task	**Very Low Workload**	....	....	....	**Very High Workload**
Unusual Attitude Recoveries					
ILS Approaches					
Vertical S "A"					
Straight and Level flight					
Vertical S "D"					
Steep Turns					

5. Does the display degrade your ability to perform these tasks in any way?
If so, explain.

_____Yes   _____No

Comments:

6. Is any display information unnecessary?

_____Yes   _____No

If so, what?

7. This display can be used as a primary flight reference with an acceptable level of safety.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Why?

8. This display format will effectively support all operational mission requirements.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Comments:

9. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience.

_____Yes _____No

If yes, explain:

10. Describe any suggestions on how the format could be improved:

11. What elements would you like to have deselectable to help reduce clutter?

12. Do you think pilots will require signficant retraining before they can safely use this format?

_____Yes   _____No

Comments:

13. Place any other comments about the CONOP Attitude Mode format below:

C-141 Primary Flight Display Questionnaire - Part 1

Format: C-141 Electromechanical **Subject Number:**____________ **Date:**____________

Instructions. This section focuses on symbology design and mechanization for the C-141 Electromechanical format. You will first be asked to evaluate various components of the format, and then to evaluate the format as a whole. Rate each item using the scale below by entering the appropriate letter in each blank. Please provide comments for any item rated as "borderline" or worse. Base your responses on your operational experience, and your participation in the simulation evaluation tasks (UARs, ILS approaches, PICT tasks, and mission demonstrations).

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

ADI

Comments:

_____ 1. Size of the ADI ball

_____ 2. Contrast between symbols and sky on the ADI ball

_____ 3. Contrast between symbols and ground on the ADI ball

_____ 4. Pitch ladder design (scale, labels, etc)

_____ 5. Pitch symbol design

_____ 6. Integration of symbols presented on the ADI

_____ 7. Pitch ladder Design / Mechanization

_____ 8. Pitch and Bank Steering Bar Design / Mechanization

_____ 9. Rising Runway Design / Mechanization

_____ 10. Bank Pointer Design / Mechanization

_____ 11. Bank Scale Precision

_____ 12. Bank Pointer Scaling

_____ 13. Color Usage on the ADI ball

_____ 14. Level of Clutter on ADI

_____ 15. Precision of Attitude Information

_____ 16. Ease of Interpretating attitude information

_____ 17. Overall ADI Design / Mechanization

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the ADI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Airspeed Indicator

Comments:

_____ 1. Displayed range of the airspeed indicator.
_____ 2. Integration / mechanization of airspeed scale components
_____ 3. Ability to quickly determine airspeed
_____ 4. Quality of trend information on the airspeed indicator
_____ 5. Airspeed scale design (tics, labels, etc)
_____ 6. Precision of airspeed information
_____ 7. Mach scale design
_____ 8. Precision of mach indicator
_____ 9. Overall design and mechanization of airspeed indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the airspeed presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Altitude Indicator

Comments:

_____ 1. Displayed range of the gross altitude indicator.

_____ 2. Displayed range of the vernier altitude indicator.

_____ 3. Quality of barometric altimeter trend information

_____ 4. Gross altitude scale design (tics, labels, etc)

_____ 5. Vernier altitude scale design (tics, labels, etc)

_____ 6. Precision of gross altitude information

_____ 7. Precision of vernier altitude information

_____ 8. Presentation of radar altitude information

_____ 9. Radar altimeter scale design

_____ 10. Precision of radar altitude information

_____ 11. Quality of trend information for radar altitude

_____ 12. Overall presentation of radar altitude information

_____ 13. Presentation of radar altitude setting

_____ 14. Presentation and placement of baro altitude setting

_____ 15. Ability to quickly determine altitude

_____ 16. Overall design and mechanization of altitude indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the altitude presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Horizontal Situation Indicator

Comments:

_____ 1. Size of the HSI

_____ 2. Integration of navigation and heading information

_____ 3. HSI scale design (tics, labels, etc)

_____ 4. Precision of heading information

_____ 5. Design and mechanization of the heading marker

_____ 6. Design and mechanization of the course arrow and CDI

_____ 7. Aircraft symbol design

_____ 8. Digital presentation of course readout

_____ 9. Bearing pointer design/mechanization

_____ 10. Presentation and placement of distance information

_____ 11. Ease of interpreting navigation information

_____ 12. Overall design and mechanization of the HSI

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the HSI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Vertical Velocity Indicator

Comments:

_____ 1. Quality of trend information

_____ 2. Range of VVI scale

_____ 3. VVI scale design (tics, labels, etc)

_____ 3. Pointer design and mechanization

_____ 4. Precision of vertical velocity information

_____ 5. Design / Mechanization of digital readouts

_____ 6. Ease of interpreting vertical velocity

_____ 7. Overall design and mechanization of vertical velocity indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the VVI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space:

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Overall Flight Display Suite

Comments:

_____ 1. Arrangement of primary flight display elements
(HSI, Altimeter, Airspeed Scale, VVI, ADI ball)
_____ 2. Integration of primary flight display components
_____ 3. Discriminability of individual symbols
_____ 4. Size of numeric labels
_____ 5. Commanded airspeed / altitude markers / digital readouts
_____ 6. Ability to perform an efficient crosscheck
_____ 7. Overall level of clutter
_____ 8. Suitability for use as a primary flight reference
_____ 9. Overall ease of interpretation of flight and navigation information
_____ 10. Overall Design and mechanization

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the overall PFD design, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

C-141 Electromechanical Format

1. Were you able to quickly determine your attitude during the UARs?

_____Yes _____No

Comments:

2. Were you able to quickly determine the correct control input during the UARs?

_____Yes _____No

Comments:

3. Does this format provide adequate information for performing the PICT and ILS tasks?

_____Yes _____No

Comments:

3. Rate your workload while performing the following tasks with the C-141 Electromechanical display format by placing a mark in the appropriate box for each task:

Task	Very Low Workload	....	....	....	Very High Workload
Unusual Attitude Recoveries					
ILS Approaches					
Vertical S "A"					
Straight and Level flight					
Vertical S "D"					
Steep Turns					

6. Does the electromechanical display format provide any unnecessary information?

_____Yes _____No

If so, what?

7. This display provides a safe primary flight reference in the C-141.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Why?

8. This display format effectively supports all operational mission requirements.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Comments:

9. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience.

_____Yes _____No

If yes, explain:

10. Place any other comments about the C-141 electromechanical format below:

C-141 Primary Flight Display Questionnaire - Part 1

Format: T-1 **Subject Number:**_____________ **Date:**___________

Instructions. This section focuses on symbology design and mechanization for the T-1 format. You will first be asked to evaluate various components of the format, and then to evaluate the format as a whole. Rate each item using the scale below by entering the appropriate letter in each blank. Please provide comments for any item rated as "borderline" or worse. Base your responses on your operational experience, and your participation in the simulation evaluation tasks (UARs, ILS approaches, PICT tasks, and mission demonstrations).

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

ADI

Comments:

_____ 1. Size of the ADI ball
_____ 2. Contrast between symbols and sky on the ADI ball
_____ 3. Contrast between symbols and ground on the ADI ball
_____ 4. Pitch ladder design (scale, labels, etc)
_____ 5. Pitch symbol design
_____ 6. Ghost horizon design / mechanization (sky or ground always shown)
_____ 7. Pitch and Bank Steering Bar Design / Mechanization
_____ 8. Bank scale design/mechanization
_____ 9. Bank pointer design
_____ 10. Bank Scale Precision
_____ 11. Integration of symbols presented on the ADI
_____ 12. Color Usage on the ADI ball
_____ 13. Level of Clutter on ADI
_____ 14. Precision of attitude information
_____ 15. Ease of Interpretating attitude information
_____ 16. AOA indicator
_____ 17. Overall ADI Design / Mechanization

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the ADI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Airspeed Indicator

Comments:

_____ 1. Pointer design and mechanization

_____ 2. Airspeed scale design (tics, labels, etc)

_____ 3. Precision of airspeed indicator

_____ 3. Design and mechanization of the digital readout

_____ 4. Presentation and placement of mach information

_____ 5. Presentation and placement of ground speed

_____ 6. Integration / mechanization of airspeed indicator components

_____ 7. Quality of airspeed trend information provided

_____ 8. Ability to quickly determine airspeed

_____ 9. Overall design and mechanization of airspeed indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the airspeed presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Altitude Indicator

Comments:

_____ 1. Altitude scale design (tics, labels, etc)

_____ 2. Pointer design and mechanization

_____ 3. Precision of altitude information

_____ 4. Digital altitude readout presentation

_____ 5. Presentation of digital radar altitude information

_____ 6. Presentation and placement of alert altitude readout

_____ 7. Presentation and placement of barometric altitimeter setting

_____ 8. Quality of altitude trend information provided

_____ 9. Ability to quickly determine altitude

_____ 10. Overall design and mechanization of altitude indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the altitude presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Horizontal Situation Indicator

Comments:

_____ 1. Size of the HSI

_____ 2. Integration of navigation and heading information

_____ 3. Heading scale design (tics, labels, etc)

_____ 4. Precision of heading information

_____ 5. Design and mechanization of the heading marker

_____ 6. Design and mechanization of the digital readout

_____ 7. Color coding usage

_____ 8. Design and mechanization of course arrow and CDI

_____ 9. Aircraft symbol design

_____ 10. Presentation of course readout

_____ 11. Bearing pointer design/mechanization

_____ 12. Presentation of bearing pointer identification information

_____ 13. Presentation and placement of distance information

_____ 14. Ease of interpreting navigation information

_____ 15. Overall design and mechanization of the HSI

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the HSI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Vertical Speed Indicator

Comments:

_____ 1. Quality of trend information provided

_____ 2. Range of VVI scale

_____ 3. VVI scale design (tics, labels, etc)

_____ 4. Pointer Design

_____ 5. Precision of vertical velocity information provided

_____ 6. Ease of interpreting vertical velocity

_____ 7. Overall design and mechanization of vertical velocity indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the VVI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space:

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

T-1 Flight Display Suite

Comments:

_____ 1. Arrangement of primary flight display elements
(HSI, Altimeter, Airspeed Scale, VVI, ADI ball)

_____ 2. Integration of primary flight display elements

_____ 3. Contrast between symbols and background

_____ 4. Discriminability of individual symbols

_____ 5. Size of numeric labels

_____ 6. Commanded airspeed / altitude presentation

_____ 7. Ability to perform an efficient crosscheck

_____ 8. Overall level of clutter

_____ 9. Color usage

_____ 10. Suitability for use as a primary flight reference

_____ 11. Overall ease of interpretation of flight and navigation information

_____ 12. Overall Design and mechanization

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the overall T-1 design, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

T-1 Format

1. Were you able to quickly determine your attitude during the UARs?

_____Yes _____No

Comments:

2. Were you able to quickly determine the correct control input during the UARs?

_____Yes _____No

Comments:

3. Does this format provide adequate information for performing the PICT and ILS tasks?

_____Yes _____No

Comments:

3. Rate your workload while performing the following tasks with the CONOP Attitude Mode format by placing a mark in the appropriate box for each task:

Task	**Very Low Workload**	....	....	....	**Very High Workload**
Unusual Attitude Recoveries					
ILS Approaches					
Vertical S "A"					
Straight and Level flight					
Vertical S "D"					
Steep Turns					

5. Does this format degrade your ability to perform these tasks in any way?
If so, explain.

_____Yes _____No

Comments:

6. Does the T-1 format provide any unnecessary information?

_____Yes _____No

If so, what?

7. This display can be used as a primary flight reference with an acceptable level of safety.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Why?

8. This display format will effectively support all operational mission requirements.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Comments:

9. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience.

_____Yes _____No

If yes, explain:

8. Describe any suggestions on how the format could be improved:

9. What elements would you like to have deselectable to help reduce clutter?

10. Place any other comments about the T-1 format below:

C-141 Primary Flight Display Questionnaire - Part 1

Format: CONOP Climb-Dive Mode **Subject Number:_____________** **Date:_____________**

Instructions. This section focuses on symbology design and mechanization for the CONOP attitude mode format. You will first be asked to evaluate various components of the format, and then to evaluate the format as a whole. Rate each item using the scale below by entering the appropriate letter in each blank. Please provide comments for any item rated as "borderline" or worse. Base your responses on your operational experience, and your participation in the simulation evaluation tasks (UARs, ILS approaches, PICT tasks, and mission demonstrations).

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

ADI

Comments:

_____ 1. Size of the ADI ball

_____ 2. Contrast between symbols and sky on the ADI ball

_____ 3. Contrast between symbols and ground on the ADI ball

_____ **4. Climb-dive ladder design (scale, labels, etc)**

_____ 5. Bendy bar design

_____ **6. Level of precision of climb-dive Information**

_____ **7. Climb-dive marker design**

_____ **8. Pitch symbol design / mechanization**

_____ **9. Flight path marker design / mechanization**

_____ 10. Speed Worm Design / Mechanization

_____ 11. Acceleration Cue Design / Mechanization

_____ 12. Ghost horizon Design / Mechanization

_____ 13. Pitch and Bank Steering Bar Design / Mechanization

_____ 14. Rising Runway Design / Mechanization

_____ 15. Bank Pointer Design / Mechanization

_____ 16. Bank Scale Precision

_____ 17. Bank Scale Design

_____ **18. Integration of symbols presented on the ADI**

_____ **19. Color Usage on the ADI**

_____ **20. Level of Clutter on ADI**

_____ **21. Ease of interpreting flight path**

_____ **22. Color of climb-dive marker (black)**

ADI (Continued)

Comments:

_____ **23. Color of pitch marker (white)**

_____ **24. Ease of interpreting climb-dive angle**

_____ **25. Ease of Interpretating attitude information**

_____ **26. Overall ADI Design / Mechanization**

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the ADI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Airspeed Indicator

Comments:

_____ 1. Displayed range of the airspeed scale.
_____ 2. Commanded Airspeed Presentation (digital and bar)
_____ 3. Airspeed scale design (tics, labels, etc)
_____ 4. Precision of airspeed indicator
_____ 5. Design and mechanization of the digital readout
_____ 6. Presentation and placement of mach information
_____ 7. Quality of airspeed trend information provided
_____ 8. Presentation and placement of ground speed
_____ 9. Integration of airspeed scale components
_____ 10. Ability to quickly determine airspeed
_____ 11. Overall design and mechanization of airspeed indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the airspeed presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Altitude Indicator

Comments:

_____ 1. Displayed range of the altitude scale
_____ 2. Quality of barometric altimeter trend information
_____ 3. Altimeter scale design (tics, labels, etc)
_____ 4. Precision of barometric altimeter
_____ 5. Design and mechanization of the digital altitude readout
_____ 6. Commanded altitude presentation (digital and bar)
_____ 7. Presentation of digital radar altitude information
_____ 8. Design and mechanization of radar altitude "thermometer" indicator
_____ 9. Quality of radar altitude trend information
_____ 10. Range of radar altitude presentation
_____ 11. Presentation and placement of alert altitude readout
_____ 12. Presentation and placement of barometric altitude setting
_____ 13. Ability to quickly determine altitude
_____ 14. Overall design and mechanization of altitude indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the altitude presentation, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Horizontal Situation Indicator

Comments:

_____ 1. Size of the HSI
_____ 2. Integration of navigation and heading information
_____ 3. HSI Scale design (tics, labels, etc)
_____ 4. Precision of heading / track information
_____ 5. Design and mechanization of the to-from indicator
_____ 5. Design and mechanization of the heading marker
_____ 6. Design and mechanization of the track cross
_____ 7. Design and mechanization of the heading diamond
_____ 8. Design and mechanization of the digital heading/track readout
_____ 9. Color coding usage
_____ 10. Design and mechanization of course arrow and CDI
_____ 11. Aircraft symbol design
_____ 12. Digital Presentation of course readout
_____ 13. Bearing pointer 1 design/mechanization
_____ 14. Bearing pointer 2 design/mechanization
_____ 15. Presentation of bearing pointer identification information
_____ 16. Presentation and placement of distance
_____ 17. HSI mode annunciations (TRU, TRK)
_____ 18. Ease of interpreting navigation information
_____ 19. Overall design and mechanization of the HSI

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the HSI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Vertical Velocity Indicator

Comments:

_____ 1. Quality of vertical velocity trend information

_____ 2. Displayed range of VVI scale

_____ 3. VVI scale design (tics, labels, etc)

_____ 4. Precision of vertical velocity information

_____ 5. Design / Mechanization of digital readout boxes

_____ 6. Design and mechanization of thermometer indicator

_____ 7. Ease of interpreting vertical velocity

_____ 8. Overall design and mechanization of vertical velocity indicator.

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the VVI, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space:

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

Overall CONOP Climb-Dive Mode format

Comments:

_____ **1. Arrangement of primary flight display elements**

(HSI, Altimeter, Airspeed Scale, VVI, ADI ball)

_____ **2. Integration of primary flight display elements**

_____ **3. Contrast between symbols and background**

_____ **4. Discriminability of individual symbols**

_____ **5. Size of numeric labels**

_____ **6. Ability to perform an efficient crosscheck with the PFD**

_____ **7. Overall level of clutter on the PFD**

_____ **8. Color usage on the PFD**

_____ **9. Suitability for use as a C-141 primary flight reference**

_____ **10. Overall ease of interpretation of flight and navigation information**

_____ **11. Overall Design and mechanization**

Please comment on any item that was rated as "borderline" or "unacceptable." Also, use this space for any other comments you may have on the overall PFD design, such as particularly good design features, or problems you had using it. Use the back of the sheet if you need more space.

CONOP Climb-Dive Mode Format

1. Were you able to quickly determine your attitude during the UARs?

_____Yes   _____No

Comments:

2. Were you able to quickly determine the correct control input during the UARs?

_____Yes   _____No

Comments:

3. Does this format provide adequate information for performing the PICT and ILS tasks?

_____Yes   _____No

Comments:

3. Rate your workload while performing the following tasks with the CONOP Climb-Dive Mode format by placing a mark in the appropriate box for each task:

Task	Very Low Workload	....	....	....	Very High Workload
Unusual Attitude Recoveries					
ILS Approaches					
Vertical S "A"					
Straight and Level flight					
Vertical S "D"					
Steep Turns					

4. Does this format degrade your ability to perform the evaluation tasks in any way?
If so, explain.

_____Yes   _____No

Comments:

5. Is any unnecessary information provided?

_____Yes   _____No

If so, what?

6. This display can be used as a primary flight reference with an acceptable level of safety.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Why?

6. This display format will effectively support all operational mission requirements.

_____Strongly Agree
_____Moderately Agree
_____Neutral
_____Moderately Disagree
_____Strongly Disagree

Why?

7. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience.

_____Yes _____No

If yes, explain:

8. Describe any suggestions on how the format could be improved:

9. What elements would you like to have deselectable to help reduce clutter?

10. Do you think that other pilots will require signficant retraining before they can safely use this format?

_____Yes _____No

Comments:

11. Place any other comments about the CONOP Climb-Dive Mode format below:

C-141 Primary Flight Display Questionnaire - Part 2

Subject Number:______________ **Date:_____________**

1. Overall, which do you most prefer?

_____ CONOP Attitude Mode

_____ CONOP Climb-Dive Mode

_____ T-1

_____ C-141 Electromechanical

Why?

2. Overall, which format do you least prefer?

_____ CONOP Attitude Mode

_____ CONOP Climb-Dive Mode

_____ T-1

_____ C-141 Electromechanical

Why?

3. Do you feel the tasks used in the simulation adequately excercised the PFD capabilities?

_____Yes _____No

If no, explain:

4. What factors, besides the display formats, contributed to your workload during the performance of the tasks?

5. Do you feel that you were able to adapt to the simulator aerodynamic model?

_____Yes _____No

Comments:

6. Please rate the following cockpit features using the scale below:

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

_____ 6.a. Flight Characteristics

_____ 6.b. Placement of displays

_____ 6.c. Throttle characteristics

_____ 6.d. Engine Displays

_____ 6.e. Overall Cockpit Geometry

_____ 6.f. Brightness of displays

_____ 6.g. Contrast of displays

Comments:

7. Based on your experience with the four formats during the simulation, your review of the MD-11, Boeing 747, and C-17 primary flight display formats, and any prior experience you may have with electronic flight displays, describe any changes or enhancements you would recommend for incorporation into the CONOP Attitude format.

7.a. Changes required for safety of flight or to support a C-141 mission function:

7.b. Desired changes:

8. Place any other comments you may have here:

APPENDIX C

Ratings and Responses from Primary Flight Display Questionnaires

CONOP ATTITUDE AND CLIMB-DIVE ELEMENT QUESTIONNAIRE RESPONSES

CONOP ATTITUDE AND CLIMB-DIVE FORMATS			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
1. ATTITUDE DIRECTOR INDICATOR	MEAN for Attitude Mode	MEAN for Climb-Dive Mode	5	4	3	2	1	5	4	3	2	1
A. Size of the ADI ball	4.78	4.72	15	2	1	0	0	14	3	1	0	0
B. Contrast between symbols and sky on the ADI ball	4.56	4.56	14	1	2	1	0	14	1	2	1	0
C. Contrast between symbols and ground on the ADI ball	4.44	4.44	12	3	2	1	0	12	3	2	1	0
D. Pitch ladder design (scale, labels, etc)	4.17	4.39	9	4	4	1	0	11	4	2	1	0
E. Bendy bar design	4.76	4.76	13	4	0	0	0	13	4	0	0	0
F. Level of Precision of Attitude Information	4.50		12	4	1	1	0					
G. Level of Precision of Climb-Dive Information		4.44						11	4	3	0	0
H. Pitch symbol design	4.50	4.33	12	4	1	1	0	9	7	1	1	0
I. Climb Dive marker design / mechanization	4.11	4.33	7	8	1	2	0	10	5	2	1	0
J. Flight path marker design / mechanization	3.72	3.83	3	8	6	1	0	4	9	3	2	0
K. Speed Worm Design / Mechanization	4.56	4.63	12	4	2	0	0	11	4	1	0	0
L. Acceleration Cue Design / Mechanization	4.38	4.44	10	3	2	1	0	11	2	2	1	0
M. Ghost horizon Design / Mechanization	4.61	4.56	13	3	2	0	0	12	4	2	0	0
N. Pitch and Bank Steering Bar Design / Mechanization	4.28	4.39	10	6	0	1	1	10	6	1	1	0
O. Rising Runway Design / Mechanization	4.38	4.44	7	8	1	0	0	8	7	1	0	0
P. Bank Pointer Design / Mechanization	4.39	4.44	11	4	2	1	0	11	5	1	1	0
Q. Bank Scale Design	4.67	4.72	13	4	1	0	0	14	3	1	0	0
R. Bank Scale Precision	4.61	4.78	13	3	2	0	0	14	4	0	0	0
S. Integration of symbols presented on the ADI	4.17	4.11	10	3	4	0	1	9	5	2	1	1
T. Color Usage on the ADI	4.59	4.44	11	5	1	0	0	12	3	2	1	0
U. Level of Clutter on ADI	3.56	3.67	2	9	5	1	1	3	9	4	1	1
V. Ease of interpreting flight path	4.12	4.22	7	6	3	1	0	7	8	3	0	0
W. Ease of interpreting climb-dive angle	4.56	4.44	12	5	0	1	0	11	5	1	1	0
X. Ease of Interpretating attitude information	4.44	4.28	12	3	2	1	0	10	5	1	2	0
Y. Color of climb-dive marker (white)	4.31	4.38	9	3	4	0	0	10	4	1	0	1
Z. Color of pitch marker (black)	4.50	4.44	12	2	1	0	1	11	3	1	0	1
AA. Overall ADI Design / Mechanization	4.11	4.11	8	5	4	1	0	7	8	1	2	0

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
2. ALTITUDE INDICATOR	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. Displayed range of the altitude scale	4.72	4.72	16	0	1	1	0	16	0	1	1	0
B. Quality of barometric altimeter trend information	4.53	4.53	12	3	1	1	0	12	3	1	1	0
C. Altimeter scale design (tics, labels, etc)	4.53	4.67	13	4	1	1	0	13	4	1	0	0
D. Precision of barometric altimeter	4.89	4.89	16	2	0	0	0	16	2	0	0	0
E. Design and mechanization of the digital altitude readout	4.22	4.22	10	3	4	1	0	10	3	4	1	0
F. Commanded altitude presentation (digital and bar)	4.11	4.11	10	4	2	0	2	10	4	2	0	2
G. Presentation of digital radar altitude information	3.83	3.89	5	5	8	0	0	6	4	8	0	0
H. Design and mechanization of radar altitude "thermometer" indicator	4.56	4.50	11	3	2	0	0	11	2	3	0	0
I. Quality of radar altitude trend information	4.07	4.13	5	6	4	0	0	6	5	4	0	0
J. Range of radar altitude presentation	4.47	4.47	13	1	2	0	1	13	1	2	0	1
K. Presentation and placement of alert altitude readout	4.11	4.11	9	5	2	1	1	9	5	2	1	1
L. Presentation and placement of barometric altitude setting	4.89	4.89	16	2	0	0	0	16	2	0	0	0
M. Ability to quickly determine altitude	4.50	4.50	13	3	1	0	1	13	3	1	0	1
N. Overall design and mechanization of altitude indicator	4.28	4.28	10	5	2	0	1	10	5	2	0	1

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
3. AIRSPEED INDICATOR	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. Displayed range of the airspeed scale.	4.94	4.94	17	1	0	0	0	17	1	0	0	0
B. Commanded Airspeed Presentation (digital and bar)	4.33	4.33	12	4	0	0	2	12	4	0	0	2
C. Airspeed scale design (tics, labels, etc)	4.53	4.59	12	4	0	0	1	13	3	0	0	1
D. Precision of airspeed indicator	4.94	4.94	17	1	0	0	0	17	1	0	0	0
E. Design / mechanization of the digital readout	4.33	4.33	11	4	2	0	1	11	4	2	0	1
F. Presentation and placement of mach information	4.41	4.47	9	6	2	0	0	10	5	2	0	0
G. Quality of airspeed trend information provided	4.28	4.29	12	3	1	0	2	12	2	1	0	2
H. Presentation and placement of ground speed	4.22	4.28	8	6	4	0	0	9	5	4	0	0
I. Integration of airspeed scale components	4.67	4.67	15	1	1	1	0	15	1	1	1	0
J. Ability to quickly determine airspeed	4.44	4.67	12	4	1	0	1	13	4	1	0	0
K. Design / mechanization of airspeed indicator	4.50	4.50	13	3	1	0	1	13	3	1	0	1

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
4. HORIZONTAL SITUATION INDICATOR	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. Size of the HSI	4.78	4.78	14	4	0	0	0	14	4	0	0	0
B. Integration of navigation and heading information	4.67	4.67	14	3	0	1	0	14	3	0	1	0
C. HSI Scale design (tics, labels, etc)	4.67		16	0	0	2	0					
D. Precision of heading / track information	4.78	4.78	15	2	1	0	0	15	2	1	0	0
E. Design and mechanization of the to-from indicator	4.79	4.79	11	3	0	0	0	11	3	0	0	0
F. Design and mechanization of the heading marker	3.94	3.94	8	5	2	2	1	8	5	2	2	1
G. Design and mechanization of the track cross	4.67	4.73	10	5	0	0	0	11	4	0	0	0
H. Design and mechanization of the digital heading/track readout	4.89	4.89	16	2	0	0	0	16	2	0	0	0
I. Color coding usage	4.67	4.67	13	4	1	0	0	13	4	1	0	0
J. Design and mechanization of course arrow and CDI	4.78	4.78	14	4	0	0	0	14	4	0	0	0
K. Aircraft symbol design	4.78	4.78	14	4	0	0	0	14	4	0	0	0
L. Digital Presentation of course readout	4.83	4.83	15	3	0	0	0	15	3	0	0	0
M. Bearing pointer 1 design/mechanization	4.44	4.44	12	3	2	1	0	12	3	2	1	0
N. Bearing pointer 2 design/mechanization	4.50	4.50	11	3	1	1	0	11	3	1	1	0
O. Presentation of bearing pointer identification information	4.89	4.89	16	2	0	0	0	16	2	0	0	0
P. Presentation and placement of distance	4.33	4.39	9	7	1	1	0	10	6	1	1	0
Q. HSI mode annunciations (TRU, TRK)	4.88	4.88	14	2	0	0	0	14	2	0	0	0
R. Ease of interpreting navigation information	4.83	4.83	15	3	0	0	0	15	3	0	0	0
S. Overall design and mechanization of the HSI	4.88	4.88	15	2	0	0	0	15	2	0	0	0

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
5. VERTICAL VELOCITY INDICATOR	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. Quality of vertical velocity trend information	4.89	4.89	16	2	0	0	0	16	2	0	0	0
B. Displayed range of VVI scale	4.89	4.89	16	2	0	0	0	16	2	0	0	0
C. VVI scale design (tics, labels, etc)	4.83	4.83	16	1	1	0	0	16	1	1	0	0
D. Precision of vertical velocity information	4.89	4.89	16	2	0	0	0	16	2	0	0	0
E. Design / Mechanization of digital readout boxes	5.00	5.00	17	0	0	0	0	17	0	0	0	0
F. Design and mechanization of thermometer indicator	5.00	5.00	17	0	0	0	0	17	0	0	0	0
G. Ease of interpreting vertical velocity	4.83	4.83	15	3	0	0	0	15	3	0	0	0
H. Overall design and mechanization of vertical velocity indicator	4.89	4.89	16	2	0	0	0	16	2	0	0	0

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb-Dive Mode				
6. OVERALL CONOP ATTITUDE AND CLIMB-DIVE FORMATS	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. Arrangement of primary flight display elements (HSI, Altimeter, Airspeed Scale, VVI, ADI ball)	4.72	4.83	13	5	0	0	0	15	3	0	0	0
B. Integration of primary flight display elements	4.56	4.39	12	5	0	1	0	11	5	1	0	1
C. Contrast between symbols and background	4.5	4.5	11	5	2	0	0	11	6	0	1	0
D. Discriminability of individual symbols	4.28	4.06	8	7	3	0	0	7	6	4	1	0
E. Size of numeric labels	4.44	4.5	12	3	2	1	0	12	4	1	1	0
F. Ability to perform an effiecient crosscheck with the PFD	4.44	4.28	12	4	1	0	1	10	6	0	1	1
G. Overall level of clutter on the PFD	3.83	3.78	3	9	6	0	0	5	6	5	2	0
H. Color usage on the PFD	4.44	4.44	11	4	3	0	0	10	7	0	1	0
I. Suitability for use as a C-141 primary flight reference	4.11	4.17	9	6	1	0	2	10	4	2	1	1
J. Overall ease of interpretation of flight and navigation information	4.28	4.28	10	5	1	2	0	9	7	0	2	0
K. Overall design and mechinization	4.06	3.94	7	8	1	1	1	5	10	1	1	1

CONOP ATTITUDE AND CLIMB-DIVE FORMATS												
			FREQUENCY for Attitude Mode					FREQUENCY for Climb -Dive Mode				
7. CONOP ATTITUDE AND CLIMB-DIVE FORMATS	**MEAN for Attitude Mode**	**MEAN for Climb-Dive Mode**				**Y**	**N**				**Y**	**N**
A. Were you able to quickly determins your attitude during the UAR's						18	0				17	1
B. Were you able to quickly determine the correct control input during the UAR's						18	0				18	0
C. Does this format provide adequate information for performing the PICT and ILS tasks						17	1				15	3
D. Does the display degrade your ability to perform these tasks in any way						7	11				7	11
E. Is any display information unnecessary						9	9				12	5
			5	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
G. This display can be used as a primary flight reference with an acceptable level of safety	4.33	4.11	12	3	1	1	1	8	6	2	2	0
H. This display format will effectively support all operational mission requirements	4.28	4.22	9	7	1	0	1	9	5	3	1	0
						Y	**N**				**Y**	**N**
I. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe, or inadequate? Consider your experience in the simulator as well as your operational experience						8	5				7	10
J. Do you think pilots will require significant retraining before they can safely use this format						9	9				7	9

CONOP ATTITUDE CONFIGURATION: Open-Ended Question Responses & Comments

1. Is any display information unnecessary? If so, what?

Subject 2: The climb dive marker and the flight path marker should be off when ATT info is displaying due to a lot of clutter.

Subject 4: Flight path angle marker.

Subject 5: I guess some info is unnecessary in certain phases of flight but none of the info is completely useless.

Subject 6: See climb dive mode Flight display questionnaire.

Subject 7: If the climb/dive symbol now gives the same info that the ACFT pitch symbol used to give, I'd say get rid of the pitch symbol. Also, I never found any use for the 'Flight Path Marker'. Clutter and extraneous extras unfamiliar symbols such as 'FLT Path MRK',----- Displace pitch REF, A/S Trend arrow and > on L. Wing tip. Also, full VVI, A/P annunciators , Marker Beacon, Loc indicator.

Subject 10: Speed worm, either : CD mkr, Flt path MKR

2. This display can be used as a primary flight reference with an acceptable level of safety. Why?

Subject 1: Beyond scale pitch representation (UAR's) make it difficult to know if your inputs are doing any good.

Subject 5: With all the trend info available and precision of readouts it should make for more precise flying. Also the display of info is clear and readable at all times and it doesn't seem in any way disturbing to fly with.

Subject 7: My only major concerns are mentioned previously. Clutter, size, contrast are my main concerns.

Subject 8: All necessary information is readily visible in a small area.

3. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience. If yes, explain:

Subject 2: With the C/D marker and flight path marker I found myself sometimes flying off the wrong reference.

Subject 5: Once you make sense of all the info available it is a very nice setup.

Subject 7: For the newly initiated, flying in IMC conditions. An exposure period with training, monitoring and check out will be necessary before certification for real IMC.

Subject 10: With present format, I would not fly and ILS with out Decluttering.

4. Describe any suggestions on how the format could be improved:

Subject 1: Command markers to the bottom (once they're set, I don't need to look at them)

Subject 2: With ATT function the climb dive should be off.

Subject 5: As stated before I didn't like where the Radar altitude was displayed

Subject 7: See comments throughout the last page. Also consider developing 2 formats: C-141 electro mechanical will minimize impact noted in #9 above.

Subject 8: Again center of pitch symbol can be last on ILS apprcaches. Perhaps if the flight path marker were only visible if it were outside the confines of the horse shoe: (See picture)

Subject 9: I would like t see a 3-digit readout of wind speed that would rotate ontop of the compass rose to show wind speed.

Subject 10: With present format, I would not fly and ILS with out Decluttering.

5. What elements would you like to have deselectable to help reduce clutter?

Subject 1: Auto pilot annunciation during manual use of flight director Dist 2.

Subject 2: C/D-Flight path

Subject 5: I haven't used it enough yet to determine this.

Subject 7: Bearing Pointers/DME; End Track/Drift angle in HDG select FLT DIR; Anything not being used, (like BRG. PTRS. in ILS mode Mach A7 low A/S and ALT.)

Subject 8: Flight path marker, climb-dive marker, Accel/Decel marker

Subject 9: Maybe have the altitude scale deselectable when on auto pilot and stabilize on ALT. leaving the selected alt displayed. Maybe do the same with the airspeed scale when on auto throttles.

Subject 10: With present format, I would not fly and ILS with out Decluttering.

6. Place any other comments about the CONOP Attitude Mode format below:

Subject 2: Over all nice design.

Subject 7: See picture on sheet.

CONOP CLIMB-DIVE CONFIGURATION: Open-Ended Question Responses & Comments

1. Is any unnecessary information provided? If so, what?

Subject 1: During ILS, I'd like to deselect the FPA.

Subject 5: Flight path marker hasn't done anything for me yet.

Subject 7: Dashed vertical pitch markers, flight path maker, acceleration cue, BRG. PTR when not in use by NAV AID, RDR altimeter until 1000 feet.

Subject 8: Acceleration/Deceleration indicator

Subject 9: Use of flight path marker for Inst. flight was unclear.

Subject 10: Speed worm, CDM, ACC CUE, FLT PATH inicator, but nice to have.

2. This display can be used as a primary flight reference with an acceptable level of safety. Why?

Subject 1: Preferred ATT function as primary.

Subject 2: It was very understandable/Easy to read.

Subject 5: Again the possible UAR problem of not recovering properly.

Subject 6: Good basic design relies of accepted standards for information plus brings other good information into easy view. My only strong suggestions for changes are moving course readout and DIST 1 and DIST 2 and having the option to declutter flight path in marker. Also, remove alert alt.

Subject 7: Especially if you enlarge, De-clutter, increase contrast and group common info items together (i.e. airspeed group = A/S, TREND, G/S, ALT Group + ALT, VVI TREND, ALTIMETER

Subject 8: All necessary information is present and grouped closely together.

Subject 10: Consolidates a lot of info. Provides a lot of trend info not previously available-will aid in detecting wind shear, performance changes.

3. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience. If yes, explain:

Subject 5: UAR

Subject 7: CAT II De-clutter plus ADD CAT II required items SOLL II low level.

Subject 10: During air refueling, If an emergency breakaway were necessary it would advantageous to have just basic attitude info.

4. Describe any suggestions on how the format could be improved:

Subject 7: See 19 Jan. Questionnaire.

Subject 8: Label the 5û or 25û lines on the ADI ladder.

Subject 10: Infinitely dimable brightness level. During air refueling, If an emergency breakaway were necessary it would advantageous to have just basic attitude info.

5. What elements would you like to have deselectable to help reduce clutter?

Subject 1: FPA, Flight path marker.

Subject 2: Waterline, flight path marker.

Subject 4: (This is question 11 for subject 4) None

Subject 7: Pitch Bar, Flight Path marker, Loc. indicator, unused BRG PTRS, and CDI (When not in use), Radar Altimeter., Choice of Flight director (Cross hairs, + or 0)

Subject 8: Airspeed ____ (See original) and Accel/Decel indicator.

Subject 10: Everything down to BASIC ATT and FLt Dir airspeed with trend and CMD MKRS, and ALT w/ CMD MKR (The only thing I would consider in uncluttered mode is FLT PATH MKR)

6. Place any other comments about the CONOP Climb-Dive Mode format below:

Subject 2: The command colors are fine for the scales, but the digital read outs could be bolder over all it will be a nice addition to the system.

Subject 6: Will definitely require training, but not significant.

Subject 8: The climb dive indicator is good for those pilots who have a tendency to forget the attitude required for level flight. It's a_**(see original, I can't tell what this says)**_____ barrier to put the climb dive marker on the horizon to stop climb on descent.

Subject 10: It seems that Climb Dive MKR and Flt Path marker duplicate- The FLT path MKR serves both needs.

C-141 ELEMENT QUESTIONNAIRE RESPONSES

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
1. ATTITUDE DIRECTOR INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
Size of the ADI ball	4.78	15	2	1	0	0
A. Contrast between symbols and sky on the ADI ball	4.78	15	2	1	0	0
B. Contrast between symbols and ground on the ADI ball	4.83	15	3	0	0	0
C. Pitch ladder design (scale, labels, etc)	4.56	12	4	2	0	0
D. Pitch symbol design	4.78	14	4	0	0	0
E. Integration of symbols presented on the ADI	4.78	14	4	0	0	0
F. Pitch ladder Design / Mechanization	4.67	13	4	1	0	0
G. Pitch and Bank Steering Bar Design / Mechanization	4.50	11	5	2	0	0
H. Rising Runway Design / Mechanization	4.71	13	3	1	0	0
I. Bank Pointer Design / Mechanization	4.61	13	3	2	0	0
J. Bank Scale Precision	4.72	14	3	1	0	0
K. Bank Pointer Scaling	4.72	14	3	1	0	0
L. Color Usage on the ADI ball	4.78	15	2	1	0	0
M. Level of Clutter on ADI	4.89	16	2	0	0	0
N. Precision of Attitude Information	4.67	12	6	0	0	0
O. Ease of Interpretating attitude information	4.67	13	4	1	0	0
P. Overall ADI Design / Mechanization	4.72	13	5	0	0	0

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
2. AIRSPEED INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Displayed range of the airspeed indicator.	4.65	12	4	1	0	0
B. Integration / mechanization of airspeed scale components	4.59	12	4	0	1	0
C. Ability to quickly determine airspeed	4.24	9	5	2	0	1
D. Quality of trend information on the airspeed indicator	4.35	9	6	1	1	0
E. Airspeed scale design (tics, labels, etc)	4.59	12	4	0	1	0
F. Precision of airspeed information	4.29	9	6	1	0	1
G. Mach scale design	4.59	11	5	1	0	0
H. Precision of mach indicator	4.88	15	2	0	0	0
I. Overall design and mechanization of airspeed indicator.	4.47	10	6	0	1	0

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
3. ALTITUDE INDICATOR	MEAN	5	4	3	2	1
A. Displayed range of the gross altitude indicator	4.72	13	5	0	0	0
B. Displayed range of the vernier altitude indicator	4.44	12	4	1	0	1
C. Quality of barometric altimeter trend information	4.56	13	4	0	0	1
D. Gross altitude scale design (tics, labels, etc)	4.61	14	2	1	1	0
E. Vernier altitude scale design (tics, labels, etc)	4.39	12	4	0	1	1
F. Precision of gross altitude information	4.72	13	5	0	0	0
G. Precision of vernier altitude information	4.56	12	5	0	1	0
H. Presentation of radar altitude information	4.17	7	8	2	1	0
I. Radar altimeter scale design	4.65	12	4	1	0	0
J. Precision of radar altitude information	4.72	14	3	1	0	0
K. Quality of trend information for radar altitude	4.81	13	3	0	0	0
L. Overall presentation of radar altitude information	4.39	10	6	1	1	0
M. Presentation of radar altitude setting	4.44	11	5	1	1	0
N. Presentation and placement of baro altitude setting	4.72	13	5	0	0	0
O. Ability to quickly determine altitude	4.11	9	5	2	1	1
P. Overall design and mechanization of altitude indicator	4.22	10	5	1	1	1

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
4. HORIZONTAL SITUATION INDICATOR	MEAN	5	4	3	2	1
A. Size of the HSI	4.67	14	2	2	0	0
B. Integration of navigation and heading information	4.61	11	7	0	0	0
C. HSI scale design (tics, labels, etc)	4.44	12	4	1	0	1
D. Precision of heading information	4.56	12	4	2	0	0
E. Design and mechanization of the heading marker	4.72	13	5	0	0	0
F. Design and mechanization of the course arrow and CDI	4.67	13	4	1	0	0
G. Aircraft symbol design	4.67	12	6	0	0	0
H. Digital presentation of course readout	4.61	12	5	1	0	0
I. Bearing pointer design/mechanization	4.56	12	4	2	0	0
J. Presentation and placement of distance information	4.61	12	5	1	0	0
K. Ease of interpreting navigation information	4.67	13	4	1	0	0
L. Overall design and mechanization of the HSI	4.61	12	5	1	0	0

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
5. VERTICAL VELOCITY INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Quality of trend information	4.67	13	4	1	0	0
B. Range of VVI scale	4.50	12	3	3	0	0
C. VVI scale design (tics, labels, etc)	4.61	14	1	3	0	0
D. Pointer design and mechanization	4.67	12	6	0	0	0
E. Precision of vertical velocity information	4.72	14	3	1	0	0
F. Design / Mechanization of digital readouts	4.65	12	4	1	0	0
G. Ease of interpreting vertical velocity	4.72	13	5	0	0	0
H. Overall design and mechanization of vertical velocity indicator	4.61	12	5	1	0	0

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
6. C-141 FLIGHT DISPLAY SUITE	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Arrangement of primary flight display elements (HSI, Altimeter, Airspeed Scale, VVI, ADI ball)	4.56	12	4	2	0	0
B. Integration of primary flight display elements	4.5	11	6	0	1	0
C. Discriminability of individual symbols	4.61	13	3	2	0	0
D. Size of numeric labels	4.78	14	4	0	0	0
E. Commanded airspeed / altitude presentation.	4.72	13	5	0	0	0
F. Ability to perform an effiecient crosscheck	4.17	8	6	3	1	0
G. Overall level of clutter	4.78	14	4	0	0	0
H. Suitability for use as a primary flight reference	4.5	12	5	0	0	1
I. Overall ease of interpretation of flight and navigation information	4.61	12	5	1	0	0
J. Overall design and mechinization	4.39	10	7	0	0	1

C-141 ELECTROMECHANICAL FORMAT						
		FREQUENCY				
7. C-141 FORMAT	**MEAN**				**Y**	**N**
A. Were you able to quickly determine your attitude during the UAR's					17	1
B. Were you able to quickly determine the correct control input during the UAR's					17	1
C. Does this format provide adequate info for performing PICT and ILS tasks					18	0
D. Does the format degrade ability to perform tasks in any waY					2	16
E. Does the C-141 Electromechanical format provide any unnecessary information					7	11
		5	**4**	**3**	**2**	**1**
F. This Display can be used as a primary flight references with an acceptable level of safety	4.33	10	6	1	0	1
G. This display format will effectively support all operational mission requirements	4.17	11	6	6	1	1
					Y	**N**
H. Are there any conditions, maneuvers, or mission flying tasks in which format would be confusioning, unsafe, or inadequate? Consider your experience in the simulator as well as your operational experience					6	11

C-141 CONFIGURATION: Open-Ended Question Responses & Comments

1. Does the electromechanical display format provide any unnecessary information? If so, what?

Subject 5: It seems to provide only the basics and makes you use your skill and experience to fill the gaps.

Subject 7: Fake command marker buttons, 'BARO' Instrumentation frames, Borders, 3D shading, etc. although it gives a Òpretty appearance in trying to emulate the 'LOOK and FEEL' of the 'Real Thing', it is of little value. Also, the works 'Climb and Dive' are really probably unnecessary.

Subject 10: An airspeed trend indicator and FLT path MKR would be useful.

2. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience. If yes, explain:

Subject 2: If you don't insure your NAV SELECT panel is set up properly you could try to shoot an ILS while in Tacan.

Subject 5: No, haven't found any yet.

Subject 7: SKE, SOLL II, CAT II (unless additions are made).

Subject 11: Trying to recover from pilot induced inverted spin.

3. Place any other comments about the C-141 electromechanical format below:

Subject 2: The markers for ALT, airspeed, command creep on the current format the ADI is adjustable, and if bumped could give improper attitude information.

Subject 7: Overall, I don't see any major problem transitioning from the current display to this one. I can see major possible improvements make with relatively minor improvements to the current display. (Such as use of color, larger displays, closer together, etc.).

Subject 10: Very simple to use. Effective, possibly not as precise as formats employing trend info.

C-141 PRIMARY FLIGHT DISPLAY - PART 2: Open-Ended Question Responses & Comments

1. Overall, which do you most prefer? Why?

Subject 1: having been trained via the control and performance concept, I prefer CONOP Attitude Mode. The Climb/Dive is great for reference only.

Subject 4: This is the system I'm most comfortable with. However if I were able to de-clutter climb-dive mode this would probably be easier.

Subject 3: CONOP Attitude mode/W climb dive selected off. Better instrumentation than 141 but I'm still used to the Att. mode. I do like the Conop C/D mode also.

Subject 5: It is similar enough to climb electromechanical but provides increase in valuable information to be very useful. A definite improvement.

Subject 6: Liked best if it had large pitch ladder scale (30degrres either side of horizon, like std. 141). Would like smaller scale selectable for precision approaches. One thing to think through on this would be: When does scale switch back to standard (larger pitch ladder scale) during a go around. One option may be when you hit the RGA button or get gear up. This could be a situational awareness problem during a critical phase of flight.

Subject 7: Easy cross check, good info. Little to no guessing. about control inputs. (One exception: FD cross hairs on ILS don't work with CDM)

Subject 8: It gives you a familiar reference (pitch symbol) as primary and then the new symbol as a backup. The black pitch symbol keeps it from blending in with the pitch scale.

Subject 9: I felt I was able to "Gnats-Ass" a lot of the parameters because of the wealth of info.

Subject 10: If the T-1 had a deselectable FLT path marker and dual swapable bearing ptrs with course swap it would be the optimum design.

2. Overall, which format do you least prefer? Why?

Subject 2: Square ADI, Vertical scale airspeed is easier to read, VVI was a good instrument, though. They all are about the same. I really like them all for different reasons.

Subject 3: Bank pointer on upper scale confuses me. I like bottom pointer.

Subject 4: Didn't seem to be as accurate.

Subject 5: It is a bit confusing to use at first. having the ADI ball and primary pitch reference moving is hard to use well.

Subject 6: I'm never going to use the climb dive markers as a primary flight reference so it shouldn't be in the center while the pitch attitude marker moves. However I did like having the climb dive marker available in Attitude Mode- very useful.

Subject 7: Round dials and clutter.

Subject 8: Scales are not as precise. VVI is erratic, in my opinion.

Subject 9: Lack of flexibility.

Subject 10: Least info, Least precise especially HSI.

3. Do you feel the tasks used in the simulation adequately excercised the PFD capabilities? If no, explain:

Subject 1: Flying some vectors to make use of the heading set marker would have helped for more adequate inputs, since that's primarily how we get to the airfield- vectors to final.

Subject 5: The combo of a bad flying Sim.. and a new display forced you to keep your eyes moving looking for specific info.

Subject 6: To a degree. First off the fly model was horrible which detracted a lot of attention away form the PFD evaluation. During PFD 3 or 4, while the pilot is flying, ask the pilot for various information from the display to see if he or she can pick it out efficiently. (i.e., whats your course, groundspeed)

4. What factors, besides the display formats, contributed to your workload during the performance of the tasks?

Subject 1: All of the 'Sim-isms' (flying characteristics of the aeromodel)

Subject 2: The aero model-it was very sloppy and a lot of work just to work.

Subject 3: Pitch trim gauge ultra sensitive, yoke fore and aft pressure not effective at all and Sim. takes much too much pressure to make left turns. It forces you to use two hands and neglect throttle movement.

Subject 4: On climb dive or attitude mode on conop too much information.

Subject 5: The SIM

Subject 6: Fly model was terrible and yoke/throttles were in an unfamiliar position.

Subject 7: A KC-135 feel system that is unbelievably un-responsive to control inputs- very distracting and frustrating. Also, the cold wx problems, computer burps, etc.

Subject 8: Flight controls. The control wheel was very stiff and required much more control deflection than any aircraft or simulator I have flown. The Sim. also kept ______ to turn to the right 2 to 4____________ was required to maneuver straight flight. (SEE THE ORIGINAL)

Subject 9: Control loading of the AERO model had a negative effect on my ability to purely concentrate on the different displays.

Subject 10: Sim"isms"-Lack of other sensory input= wind noise, control, feed back , etc., Diff aero model. Sim Didn't pick up small right bank inputs very well. I found myself just using R rudder to make the input. Adusting to diff formats and electronic displays: I've never flown with anything other than electromechanical cal. til now.

5. Based on your experience with the four formats during the simulation, your review of the MD-11, Boeing 747, and C-17 primary flight display formats, and any prior experience you may have with electronic flight displays, describe any changes or enhancements you would recommend for incorporation into the CONOP Attitude format.

Subject 10: See previous questionnaire. I like the tape background on MD-11/7v7 displays. I like the MD-11's A/S CMD MKR design.

5a. Changes required for safety of flight or to support a C-141 mission function:

Subject 2: None.

Subject 3: None.

Subject 5: Procedure changes when in climb/dive for ensuring the pitch marker as primary pitch reference.

Subject 6: All previous evaluations still hold, nothing new to add now.

Subject 9: As briefed in previous write-ups one major item I wuld add would be a backlit warning light when one pilot takes a handoff of the other pilot's DAMU display.

5b. Desired changes:

Subject 1: Instead of a tape on the VVI, a caret would be easier to see peripherally. Some type of marker every five hundred feet on the altimeter. Upper reference for wings level. (See drawing). Place warning annunciators on side of display instead of top. Standard increments for scale on the ADI.

Subject 4: During your testing, Perform each maneuver as you do now but, do them again with ADI de-cluttered.

Subject 6: See previous evaluations.

Subject 8: V-bar flight director easier to follow and less clutter. Put VVI outside the altimeter.

Subject 10: If there was a way to incoporate turn and slip info close to ADI like T-1 design it would be an improvement.

6. Place any other comments you may have here:

Subject 1: DAMU Design B was a good setup.

Subject 10: I would like to test an ADI that had a digital readout of pitch attitude in tenths for fine tuning pitch. A button that you could tap to store all info on PFD or SFD at any instant for later review would be very useful. Some examples: 1. Write OPS (mx) requiring flt conditions. 2. Training (Ht speed, hdg, drift, bank, etc. over thld or lndg.) 3. Emergency procedures. It is very important that the DAMU doesn't restrict vis. That SKE equip up on the dash does anol it is constantly annoying all sensible pilots.

T-1 ELEMENT QUESTIONNAIRE RESPONSES

T-1 FORMAT						
		FREQUENCY				
1. ALTITUDE DIRECTION INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Size of the ADI ball	4.89	16	2	0	0	0
B. Contrast between symbols and sky on the ADI ball	4.94	17	1	0	0	0
C. Contrast between symbols and ground on the ADI ball	4.94	16	1	0	0	0
D. Pitch ladder design (scale, labels, etc)	4.89	16	2	0	0	0
E. Pitch symbol design	4.71	12	5	0	0	0
F. Ghost horizon design / mechanization (sky or ground always shown)	4.61	13	3	2	0	0
G. Pitch and Bank Steering Bar Design / Mechanization	4.72	14	3	1	0	0
H. Bank Scale design / mechanization	4.39	11	4	2	1	0
I. Bank pointer design	4.61	13	3	2	0	0
J. Bank Scale Precision	4.50	11	6	0	1	0
K. Integration of symbols presented on the ADI	4.78	14	4	0	0	0
L. Color Usage on the ADI ball	4.83	16	1	1	0	0
M. Level of Clutter on ADI	4.89	16	2	0	0	0
N. Precision of Attitude Information	4.83	16	1	1	0	0
O. Ease of Interpretating attitude information	4.83	16	1	1	0	0
P. AOA indicator	4.50	11	5	2	0	0
Q. Overall ADI Design / Mechanization	4.61	13	3	2	0	0

T-1 FORMAT						
		FREQUENCY				
2. AIRSPEED INDICATOR	**MEAN**	5	4	3	2	1
A. Pointer design and mechanization.	4.44	13	2	1	2	0
B. Airspeed scale design (tics, labels, etc)	4.61	12	4	1	1	0
C. Precision of airspeed indicator	4.50	16	1	0	0	1
D. Design and mechanization of the digital readout	4.72	16	2	0	0	0
E. Presentation and placement of mach information	4.89	8	7	2	0	0
F. Presentation and placement of ground speed	4.35	10	5	2	0	0
G. Integration / mechanization of airspeed indicator components	4.47	14	3	0	1	0
H. Quality of airspeed trend information provided	4.67	13	3	1	0	1
I. Ability to quickly determine airspeed	4.50	15	2	1	0	0
J. Overall design and mechanization of airspeed indicator.	4.78	12	5	1	0	0

T-1 FORMAT						
		FREQUENCY				
3. ALTITUDE INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Altitude scale design (tics, labels, etc)	4.67	14	3	0	1	0
B. Pointer design and mechanization	4.72	14	3	1	0	0
C. Precision of altitude information	4.78	15	2	1	0	0
D. Digital altitude readout presentation	4.78	16	1	0	1	0
E. Presentation of digital radar altitude information	4.61	15	0	2	1	0
F. Presentation and placement of alert altitude readout	4.17	13	2	0	1	0
G. Presentation and placement of barometric altitimeter setting	4.94	17	1	0	0	0
H. Quality of altitude trend information provided	4.78	15	2	1	0	0
I. Ability to quickly determine altitude	4.78	15	2	1	0	0
J. Overall design and mechanization of altitude indicator.	4.78	14	2	2	0	0

T-1 FORMAT						
		FREQUENCY				
4. HORIZONTAL SITUATION INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Size of the HSI	4.78	15	2	1	0	0
B. Integration of navigation and heading information	4.50	13	3	1	0	1
C. Heading scale design (tics, labels, etc)	4.74	14	4	0	0	0
D. Precision of heading information	4.67	13	4	1	0	0
E. Design and mechanization of the heading marker	4.61	13	3	2	0	0
F. Design and mechanization of the digital readout	4.72	14	3	1	0	0
G. Color coding usage	4.44	10	6	2	0	0
H. Design and mechanization of course arrow and CDI	4.72	14	3	1	0	0
I. Aircraft symbol design	4.89	16	2	0	0	0
J. Presentation of course readout	4.61	11	7	0	0	0
K. Bearing pointer design/mechanization	3.78	5	6	6	0	1
L. Presentation of bearing pointer identification information	4.28	9	7	1	0	1
M. Presentation and placement of distance information	4.78	14	4	0	0	0
N. Ease of interpreting navigation information	4.67	12	6	0	0	0
O. Overall design and mechanization of the HSI	4.39	9	8	0	1	0

T-1 FORMAT						
		FREQUENCY				
5. VERTICAL VELOCITY INDICATOR	**MEAN**	**5**	**4**	**3**	**2**	**1**
1. Quality of trend information	4.83	15	3	0	0	0
2. Range of VVI scale	4.89	16	2	0	0	0
3. VVI scale design (tics, labels, etc)	4.83	15	3	0	0	0
4. Pointer design	4.83	16	1	1	0	0
5. Precision of vertical velocity information	4.83	15	3	0	0	0
6. Ease of interpreting vertical velocity	4.78	14	4	0	0	0
7. Overall design and mechanization of vertical velocity indicator.	4.78	14	4	0	0	0

T-1 FORMAT						
		FREQUENCY				
6. OVERALL T-1 FLIGHT DISPLAY FORMAT	**MEAN**	**5**	**4**	**3**	**2**	**1**
A. Arrangement of primary flight display elements (HSI, Altimeter, Airspeed Scale, VVI, ADI ball)	4.47	11	4	1	1	0
B. Integration of primary flight display elements	4.76	14	2	1	0	0
C. Discriminability of individual symbols	4.41	10	5	1	1	0
D. Size of numeric labels	4.71	13	3	1	0	0
E. Commanded airspeed / altitude presentation.	4.53	11	4	2	0	0
F. Ability to perform an effiecient crosscheck	4.59	11	5	1	0	0
G. Overall level of clutter	4.71	13	3	1	0	0
H. Suitability for use as a primary flight reference	4.59	12	4	0	1	0
I. Overall ease of interpretation of flight and navigation information	4.65	13	3	0	1	0
J. Overall design and mechinization	4.65	12	4	1	0	0

T-1 FORMAT						
		FREQUENCY				
7. T-1 FORMAT	**MEAN**				**Y**	**N**
A. Were you able to quickly determine your attitude during the UAR's					18	0
B. Were you able to quickly determine the correct control input during the UAR's					18	0
C. Does this format provide adequate info for performing PICT and ILS tasks					18	0
D. Does the format degrade ability to perform tasks in any way					14	4
E. Does the T-1 format provide any unnecessary information					7	11
		5	**4**	**3**	**2**	**1**
F. This Display can be used as a primary flight references with an acceptable level of safety	4.78	14	4	0	0	0
G. This display format will effectively support all operational mission requirements	4.5	11	6	0	1	0
					Y	**N**
H. Are there any conditions, maneuvers, or mission flying tasks in which format would be confusioning, unsafe, or inadequate? Consider your experience in the simulator as well as your operational experience					3	15

T-1 CONFIGURATION: Open-Ended Question Responses & Comments

1. Does the T-1 format provide any unneccessary information?

Subject 1: The Fast/Slow indication.

Subject 5: I didn't know if the T-1 does or if the C-141 will start using AOA info but I didn't need it.

Subject 7: A.O.A

2. Are there any conditions, maneuvers or mission flying tasks in which this format would be confusing, unsafe or inadequate? Consider your experience in the simulator as well as your operational experience. If yes, explain:

Subject 7: It won't serve SKE, and I'm not sure it would serve for CAT II, AR, or SOLL II.

3. Describe any suggestions on how the format could be improved:

Subject 1: Bearing pointer changed.

Subject 3: Move VVI information up somewhere on or near the altimeter.

Subject 6: See individual instrument evaluation

Subject 7: Make ADI and HSI larger A/S and ALT linear/Digital color changes.

Subject 8: Have an option to enlarge the top portion (60 degree or so) of the HSI to allow for more precise flying.

Subject 9: Redesign the bearing pointer.

Subject 10: Deselctable FLT Path trend MKR, A/S CMD MKR on outside of scale. More precise bank scale. Bearing Pointer chnages mentioned earlier.

4. What elements would you like to have deselectable to help reduce clutter?

Subject 1: Maybe have the ADA gage selectable

Subject 4: ADA

Subject 5: AOA

Subject 6: AOA gauge, but AOA would be nice to have in case pilot static system goes out.

Subject 7: A.O.A., Lat., DEV., RDR.,ALT., RAT., TAS.,S.H.

Subject 8: AOA indicator.

Subject 9: Very neat display, no noticable clutter.

5. Place any other comments about the T-1 format below:

Subject 7: Add a turn indicator back to the slip indicator.

Subject 8: The large arrows at the extreme top and bottom of ADI are helpful in extreme situations.

Subject 10: The CDI at bottom of ADI is another nice feature. This format is extremely well designed for easy use. The expanded scale and FLT path trend info of theConop may after accustomization result in more precision.

APPENDIX D

Description of Display Avionics Management Unit (DAMU) Functions

DISPLAY AVIONICS MANAGEMENT UNIT

NAV SELECT

The NAV SELECT menu provides the pilot and copilot with the capability to control navigation system input to the AFCS and for flight direction. This, in turn, affects the display of the Attitude Director Indicator (ADI) and Horizontal Situation Indicator (HSI) located on the Primary Flight Display (PFD) and the expanded HSI and MAP display located on the Secondary Flight Display (SFD). The NAV SELECT menu also provides the pilot and the copilot with the ability to control the mode of the AFCS flight director and to select which navigational aides are connected to the Bearing Pointers 1 and 2 on the HSI (PFD) and on the MAP (SFD) and Expanded HSI (SFD).

BEARING POINTER 1 RADIO-BASED NAVAIDS

Selects radio navigational input to the AFCS for flight direction, on the ADI and the course deviation indicator (CDI) within the HSI, and to Bearing Pointer 1 (i.e., PTR1). This selection will affect the pilot/copilot PFD , which contain flight director steering and glideslope information on the ADI, and navigation information on the HSI and CDI. The autopilot shall automatically fly the aircraft based on the selected radio-based input (except for ADF1 and ADF2). The selected navigational input shall be annunciated on the PTR1 legend on the PFD.
* Only one selection can be made to PTR1

OPTIONS	FUNCTIONS
TAC 1	Connects TACAN 1 to the AFCS for flight direction on the PFD and SFD pages
TAC 2	Connects TACAN 2 to the AFCS for flight direction on the PFD and SFD pages
VOR/ILS 1	VHF Omni-Range/Instrument Landing System 1. Connects VOR/ILS 1 to the AFCS for flight direction on the PFD and SFD pages.
VOR/ILS 2	VHF Omni-Range/Instrument Landing System I. Connects VOR/ILS 2 to the AFCS for flight direction on the PFD and SFD pages.
ADF 1	Auto Direction Finder. Only connects ADF1 to bearing pointer 1 on the PFD and SFD HSIs and on SFD MAP. No flight guidance to the AFCS.
ADF 2	Auto Direction Finder. Only connects ADF1 to bearing pointer 1 on the PFD and SFD HSIs and on SFD MAP. No flight guidance to the AFCS.
[MLS 1]	Microwave Landing System 1. Growth option.
[MLS 2]	Microwave Landing System 2. Growth option.

BEARING POINTER 1 AREA NAVIGATION AIDS	
Selects navigational-based sources for input to the AFCS for flight direction, on the ADI and Course Deviation Indicator (CDI) within the HSI, and to Bearing Pointer 1 (i.e., PTR1). This selection will affect the pilot/copilot PFD which contains flight director steering and glideslope information on the ADI and CDI. The autopilot shall automatically fly the aircraft based on the selected radio-based input (except for ADF1 and ADF2). Options are selected from the right DAMU screen with active selection reversed video highlighted	
OPTIONS	FUNCTION
INS1	Inputs the INS 1 cross track deviation to the AFCS for flight direction. Shall display track angle to Bearing Pointer 1 on the HSI and shall input true HDG to the HSI (to change to magnetic hdg, select MAG for HSI on the PFD Config page in the DAMU.
INS2	Inputs the INS 2 cross track deviation to the AFCS for flight direction. Shall display track angle to Bearing Pointer 1 on the HSI and shall input true HDG to the HSI (to change to magnetic hdg, select MAG for HSI on the PFD Config page in the DAMU.
[GPS]	Global Positioning System. Growth option.
[KNS]	Kalman Navigation Solution. Growth option.

BEARING POINTER 2	
Selects navigation sources to be connected to Bearing Pointer 2 on the HSI (PFD page) and the expanded HSI and MAP (SFD pages).	
OPTIONS	FUNCTION
TAC 1	Connects TACAN 1 to Bearing Pointer 2 on the HSI (PFD)
TAC 2	Connects TACAN 2 to Bearing Pointer 2 on the HSI (PFD)
VOR/ILS 1	VHF Omni-Range/Instrument Landing System 1. Connects VOR1 or ILS1 (depending on radio signal) to Bearing Pointer 2 on the HSI (PFD).
VOR/ILS 2	VHF Omni-Range/Instrument Landing System I. Connects VOR2 or ILS2 (depending on signal) to Bearing Pointer 2 on the HSI (PFD).
ADF 1	Auto Direction Finder. Connects ADF1 to Bearing Pointer 2 on the HSI (PFD).
ADF 2	Auto Direction Finder. Only connects ADF2 to Bearing Pointer 2 on the HSI (PFD).
OFF	Bearing Pointer 2 is not displayed.

AUTO-PILOT/FLIGHT DIRECTOR MODE	
Selects mode options for the autopilot/flight director. These options, once selected, affect the autopilot and flight direction (except in BASIC) functions ADI and HSI on the PFD page and the SFD page when in expanded HSI mode.	
OPTIONS	FUNCTION
BASIC	Basic autopilot mode. Causes the autopilot to revert to the basic attitude mode of operation (i.e., maintains current attitude). Turns flight director steering bars off except when in SKE (only roll bar displayed).
HDG	Heading. Causes AFCS flight director to guide the aircraft to the heading set marker which is set via the AFCS Reference Set Panel or the old HSI and to display flight director indicators on the ADI when the FD switch on the Mode Select Panel.
LNAV	Lateral Navigation. Causes the AFCS flight director guide the aircraft to intercept and track the course which is displayed on the CDI (if within the capture zone). If an ILS frequency is selected, no glideslope or pitch steering is provided on the ADI.
AWLS	All Weather Landing System. Functions like LNAV except it provides increased bank-steering bar sensitivity, glideslope information, and pitch steering when an ILS frequency is selected. Cannot be selected if SKE is also selected.
SKE	Station Keeping Equipment. Replaces the ADI select switch on the P/CP side consoles. Toggles between ON and OFF. ON selection provides SKE output to flight director bank steering. Causes SKE range (left side of the ADI), SKE cross track (below ADI), and SKE altitude (right side of the ADI) scales to be generated on the PFD page. Causes speed deviation bar on flight path or attitude marker to indicate appropriate speed up or slow down commands required to maintain proper SKE range. This option can be selected only when AP/FD is in either BASIC or HDG mode. (This switch does not repeat multi-function azimuth range information - which is an option in the SFD menu).

ATTITUDE REFERENCE SETTING	
Selects attitude source for input to the AFCS and pilot's and copilot's ADI. The selected attitude source shall be also annuciated on top the PFD.	
OPTIONS	FUNCTION
INS1	Inertial Navigation System. Selects INS1 as the source of attitude data for the AFCS and the ADI.
INS2	Inertial Navigation System. Selects INS2 as the source of attitude data for the AFCS and the ADI.
AHRS	Attitude Heading Reference System. Selects AHRS as the source of attitude data for the AFCS and the ADI.

HEADING REFERENCE SETTING
Selects attitude source for input to the AFCS and for display on the HSI (PFD) and the HSI and MAP (SFD). The selected heading source shall be also annuciated on top of the PFD.

OPTIONS	FUNCTION
INS1	Inertial Navigation System. Selects INS1 as the source of heading data for the AFCS and the ADI.
INS2	Inertial Navigation System. Selects INS2 as the source of heading data for the AFCS and the HSI (PFD/ SFD) and MAP (SFD).
AHRS	Attitude Heading Reference System. Selects AHRS as the source of heading data for the HSI (PFD/SFD) and MAP (SFD).

FSAS/CDU REPEAT
Causes the current FSAS/CDU page to be repeated on the DAMU screen. No changes can be made to this page.

PRIMARY FLIGHT DISPLAY CONFIGURATION

Provides the ability to independently control the configuration of the PFD. There shall be separate PFD menus for the pilot and copilot, signified by "P" for pilot and "CP" for copilot, in the menu title line.

ADI MODE	
Selects between the traditional attitude (ATT) and climb-dive (CD) presentation on the ADI on the PFD page.	
OPTIONS	FUNCTION
ATT	Causes traditional attitude format to be displayed on the ADI.
CD / FPATH	Causes climb-dive (flight path) format to be displayed on the ADI.

FLIGHT PATH ANGLE	
Allows the pilot/copilot to turn on or off the display of the Climb-Dive marker and desired Flight Path Angle.	
OPTIONS	FUNCTION
up arrow	Allows the Flight Path Angle to be incremented in 0.1 degrees. The range is from 9.9 to -9.9 degrees. Selections can be made by pressing and holding the key until desired angle is displayed.
down arrow	Allows the Flight Path Angle to be decrement in 0.1 degrees. The range is from 9.9 to -9.9 degrees. Selections can be made by pressing and holding the key until desired angle is displayed.

FLIGHT DIRECTOR STEERING CUES	
Toggles between BARS and BALL flight director steering cues on the ADI (on the PFD).	
OPTIONS	FUNCTION
BARS	Causes traditional pitch and bank steering bars to be displayed on the ADI .
BALL	Causes a single ball to be displayed on the ADI to provide both flight director pitch and bank steering from a single integrated cue. * Option is only available with ADI in CD and with both pitch and roll flight director. (e.g., when in SKE mode, localizer only approach).

ALTITUDE SCALE SETTING	
Toggles between feet and meters for display of altitude scale information, which is displayed to the right of the ADI on the pilot/copilot PFD.	
OPTIONS	FUNCTION
FT	Causes normal barometric altitude to be displayed in FEET on the altitude scale. Since the default is feet, no labeling indicating the scale is in feet will be displayed on the PFD.
MTR	Causes barometric altitude to be displayed in METERS on the altitude scale with METERS displayed at the bottom of the scale of the PFD and M between the tape numbers.

HSI DISPLAY MODE	
Toggles between "heading up" (HDG) or "track up" (TRK) presentations on the HSI (on the PFD). Option only available when navigating in INS (i.e., Bearing Pointer 1 is in INS1 or INS2). Otherwise default is always heading-up.	
OPTIONS	FUNCTION
HDG	Causes the HSI compass to rotate such that aircraft heading is at the top of the HSI. Aircraft ground track to be presented by a solid cross symbol. Causes a numeric readout of the heading to be displayed within the box.
TRK	Causes the HSI compass to rotate such that the aircraft ground track is at the top of the HSI. Causes TRK to be displayed on the left side of the box at the top of the HSI and a numeric readout to be displayed within the box.

HSI HEADING MODE	
Toggles between Synthetic Magnetic or True heading modes while navigating in INS1 or INS2.	
OPTIONS	FUNCTION
TRUE	Causes heading on the HSI page on the PFD and SFD and MAP to be displayed in true heading mode.
MAG	Causes heading on the HSI page on the PFD and SFD and MAP to be displayed in synthetic magnetic mode. Causes MAG to be displayed on the right side of the box at the top of the HSI on the right.

BAROMETRIC ALTITUDE REFERENCE SETTING	
Toggles between inches (IN) or millibars (MB) format for the barometric altitude reference setting, which is displayed below the altitude scale to the right of the ADI on the pilot or copilot's PFD page.	
OPTIONS	FUNCTION
IN	Causes the barometric altitude reference setting to be numerically displayed on the PFD in inches of mercury.
MB	Causes the barometric altitude reference setting to be numerically displayed on the PFD in millibars with MB displayed adjacent to the numeric readout.

SECONDARY FLIGHT DISPLAY CONFIGURATION

Provides the pilots with the ability to independently control the configuration of the SFD pages. There shall be separate SFD menus for the pilot and copilot, signified by "P" for pilot and "CP" for copilot, in the menu title line.

MAP DISPLAY		
Causes MAP to be displayed on the SFD.		
OPTIONS	TOGGLE SELECTIONS	FUNCTION
RADAR	ON / OFF	Turns on or off the overlay of color radar video onto the SFD MAP.
TACAN	ON / OFF	Turns on or off the display of the TACAN stations.
up arrow - RANGE	5 / 25 / 50 / 150 / 300	Increases the range of the MAP from previous selection.
dn arrow - RANGE	5 / 25 / 50 / 150 / 300	Decreases the range of the MAP from previous selection.
[APRTS]	ON / OFF	Airfield symbol (s) along the flight route. Growth option.
[THRTS]	ON / OFF	Threats. Growth option.

SKE DISPLAY
Causes the SKE display (currently generated on the AN/APS-133 MFD in the pilot's center instrument panel) to be displayed on the SFD page. Displays proximity to other aircraft in formation and azimuth range. *Option not available unless SKE system Primary Control is in XMIT mode.

EXPANDED HSI DISPLAY
Causes an expanded HSI to be displayed on the SFD page.

ZONE MARKER
Toggles between ON and OFF. When ON is selected, causes the interrogated SKE zone marker to be displayed on the MAP. When OFF is selected, causes the SKE zone marker to be displayed as a trailing aircraft.

WIND DIRECTION / DRIFT ANGLE	
Selects wind direction, drift angle or both for display on the SFD page.	
OPTIONS	FUNCTION
WIND	Causes wind direction to be displayed on any of the SFD pages.
DRIFT	Causes aircraft drift angle to be displayed on any of the SFD pages.
BOTH	Causes both wind direction and aircraft drift angle to be displayed on the any of the SFD pages.

DISPLAY CONTROL MENU

The DISPLAY CONTROL menu provides the ability to control the configuration and display mode of the DAMU displays and to select the processor unit, location, and display mode for PFD and SFD displays. There are separate DISPLAY CONTROL menus for the pilot and copilot, signified by "P" for pilot and "CP" for copilot, in the menu title line.

CONTROL DISPLAY SYSTEMS MODE

Selects between NORMAL and NIGHT VISION GOGGLES mode for the DAMU displays and the PFD/ SFD displays.

OPTIONS	FUNCTIONS
NORMAL	Places the display units and DAMU screens in normal brightness and color mode.
NVG	Places the display units and DAMU screens in a lighting mode that is compatible with Night Vision Goggles (NVG)

OUTBOARD DISPLAY OPTIONS

Selects display options for the outboard display unit.

OPTIONS	FUNCTION
PFD	Places the PFD on the outboard DU.
SFD	Places the SFD on the outboard DU.
PFD - REPEAT	Repeats the other crew member's PFD on the outboard DU.
SFD - REPEAT	Repeats the other crew member's SFD on the outboard DU.

INBOARD DISPLAY OPTIONS

Selects display options for the inboard display unit.

OPTIONS	FUNCTION
PFD	Places the PFD on the inboard DU.
SFD	Places the SFD on the inboard DU.
PFD - REPEAT	Repeats the other crew members PFD on the inboard DU.
SFD - REPEAT	Repeats the other crew members SFD on the inboard DU.

DISPLAY DPU SELECT

Selects which processor unit (1 or 2) generates the crew member's PFD and SFD displays.
* Processor 1 is default for pilot DUs and processor 2 is default for copilot DUs.

HANDOFF

Enables handoff of DAMU displays and controls when ON is selected.

DAMU CONTROL

Calls up the other crew members (pilot or copilot) DAMU menus for control. The default is PILOT for pilot's DAMU and COPILOT for the copilot's menus.
*Handoff must be turned ON on the other crew member's DAMU DISPLAY CONTROL page for the DAMU CNTRL to be operational.

APPENDIX E

Menu Structures for Both DAMU Designs

Purpose and Description:

The Damu (Display Avionics Management Unit) provides for the majority of the man-machine interface capability to the control display system (CDS) and navigational systems through the use of a menu system.

Each DAMU display has a right and left display screen with each screen having four line select keys (LSK) on either side, providing a total of eight line select keys per screen and sixteen line select keys per DAMU display. These keys are used for immediate activation of the line item or for the selection of line item options.

Because the pilot/copilot has the capability to call up the other's DAMU menu system, the menu titles for all menus except the MAIN MENU (which is the same for either crew member) will show either (-P) for pilot or (-CP) for copilot.

Menu Navigation:

The following figures illustrate the hierarchical menu structure of the CONOP version of the DAMU menu system.

The left DAMU screen shall display the MAIN menu, primary menus (NAV SELECT, PFD, SFD, DISPLAY CONTROL, BIT) and FSAS/CDU REPEAT. (The BIT menu will not be available for testing.) Upon activation of a key on the MAIN MENU screen, the corresponding menu is selected(NAV SELECT, PFD, SFD, DISPLAY CONTROL, BIT, or FSAS/CDU REPEAT). Newly selected primary menus and their associated right screen default pages (if any) will override any previously selected primary page on the DAMU screens. For the primary menus, depressing a line select key causes the selection of an item which is in line immediately adjacent to the key or causes a page with line item options to be displayed on the right screen.

The right screen shall display the appropriate item options which are dependent upon the selected left menu element. The NAV SELECT on the left DAMU screen and the STATUS menu on the right DAMU screen have the same menu elements and thus have the same 6 pages. The PFD CONFIG menu has 1 page which is always displayed on the right DAMU screen. The SFD config has 2 pages, and the DISPLAY CONTROL has 3 pages. Refer to the following figures.

Feedback:

Active line items are highlighted in reverse video on both left and right DAMU screens.

Symbol Conventions:

Item selections which can be made on the left DAMU screen are indicated by a dash following line item label.

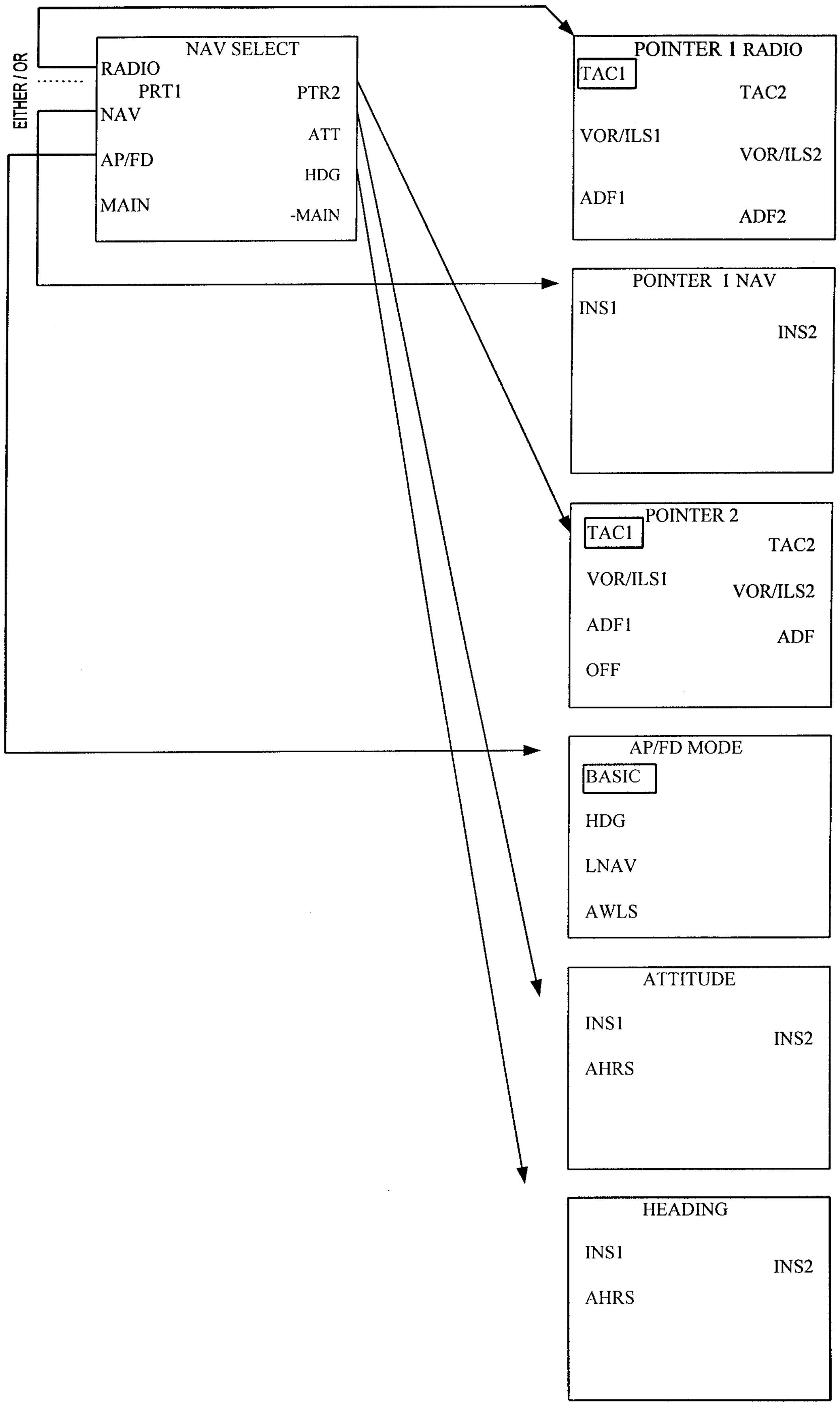


FIGURE 1. NAV SELECT MENU HIERARCHY - CONOP FORMAT

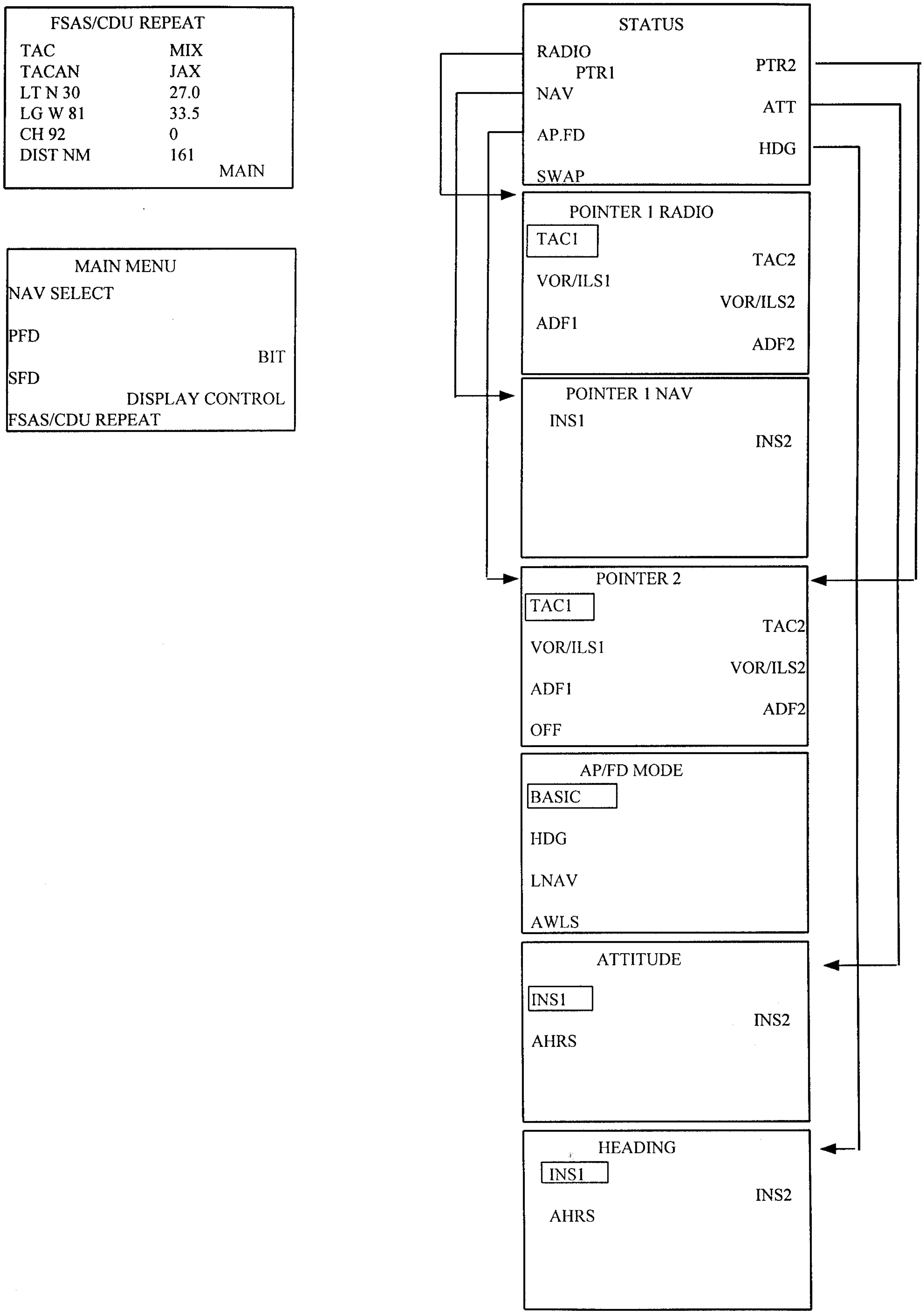


FIGURE 2. FSAS/CDU / MAIN/ STATUS MENU HIERARCHY CONOP FORMAT

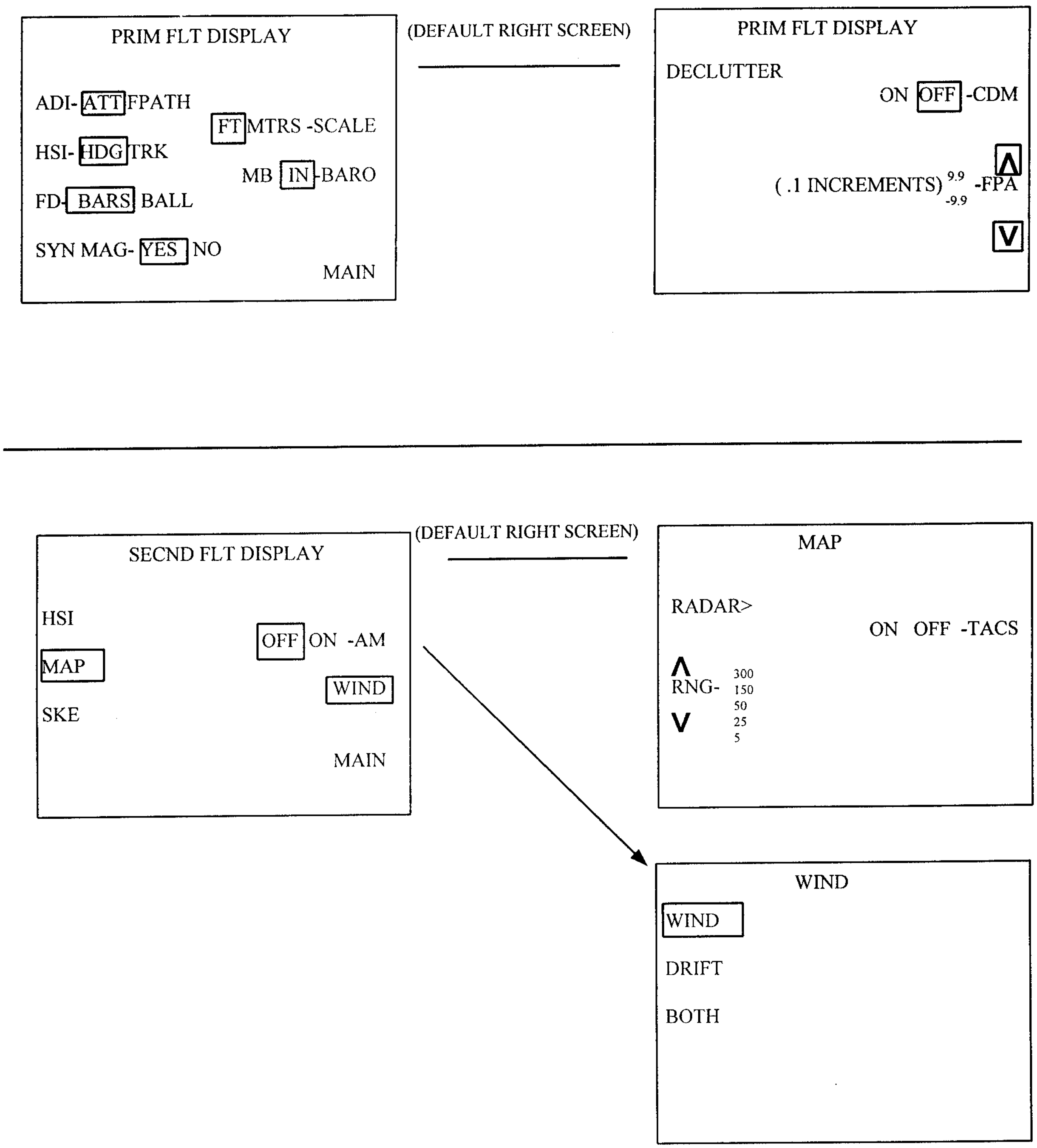


FIGURE 3. PFD/SFD MENU HIERARCHY - CONOP FORMAT

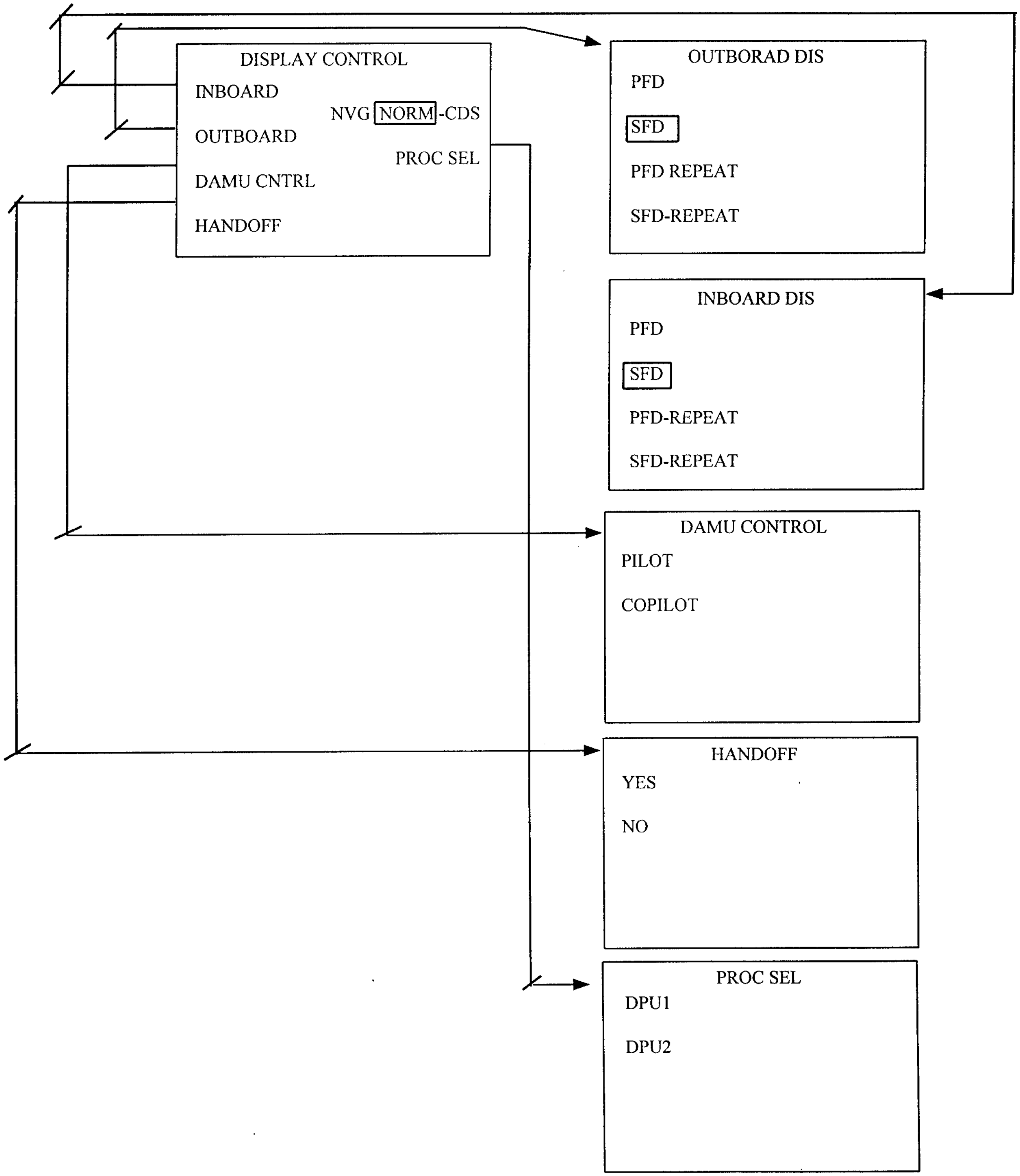


FIGURE 4. DISPLAY CONTROL MENU HIERARCHY - CONOP FORMAT

Purpose and Description:
The DAMU (Display Avionics Management Unit) provides for the majority of the man-machine interface capability to the control display system (CDS) and navigational systems through the use of a menu system.

Each DAMU display has a right and left display screen with each screen having four line select keys (LSKs) on either side, providing a total of eight line select keys per screen and sixteen line select keys per DAMU display. These keys are used for immediate activation of the line item (denoted by no symbol following the line item) or for the selection and or activation of line item options (denoted by either a dash [-] for page options or a caret [>] for toggle options. (Symbol conventions are discussed later.)

Because the pilot/copilot has the capability to call up the other's DAMU menu system, the menu titles for all menus except the MAIN MENU (which is the same for either crew member) will show either (-P) for pilot or (-CP) for copilot.

Menu Navigation:
Figures 1, 2, and 3 illustrate the hierarchical menu structure of the FIP version of the DAMU menu system.

The left DAMU screen presents the pages for the five primary menus: NAV SELECT, PFD CONFIG, SFD CONFIG, DIS CNTRL and BIT). (The BIT page will not be operational for this evaluation.) The primary menu pages can be accessed by pressing the MAIN line select key located on the bottom right key on the left DAMU screen. The MAIN line select key acts as a "go to" button allowing the other four primary pages to any previously selected pages on the DAMU screens.

The right DAMU screen presents second order options for the NAV SELECT and DISPLAY CONTROL menus. For the PFD CONFIG and SFD CONFIG menus, the default right DAMU screen presents a continuation of the menu line items. The NAV SELECT menu has 6 pages which can be displayed on the right DAMU screen; the PFD CONFIG menu has 2 pages, the SFD CONFIG has 2 pages, and the DISPLAY CONTROL has 4 pages. Refer to Figures 1, 2, and 3.

Feedback:
Active line item selections will be reserved video highlighted on the right DAMU screen for the NAV SELECT and DISPLAY CONTROL page options. This is illustrated in the Figures 1, 2, and 3 as a box drawn around the line item. Active line items will not be highlighted on the left DAMU screen except in the SFD CONFIG menu for the MAP, HSI, and SKE selection (only one can be selected).

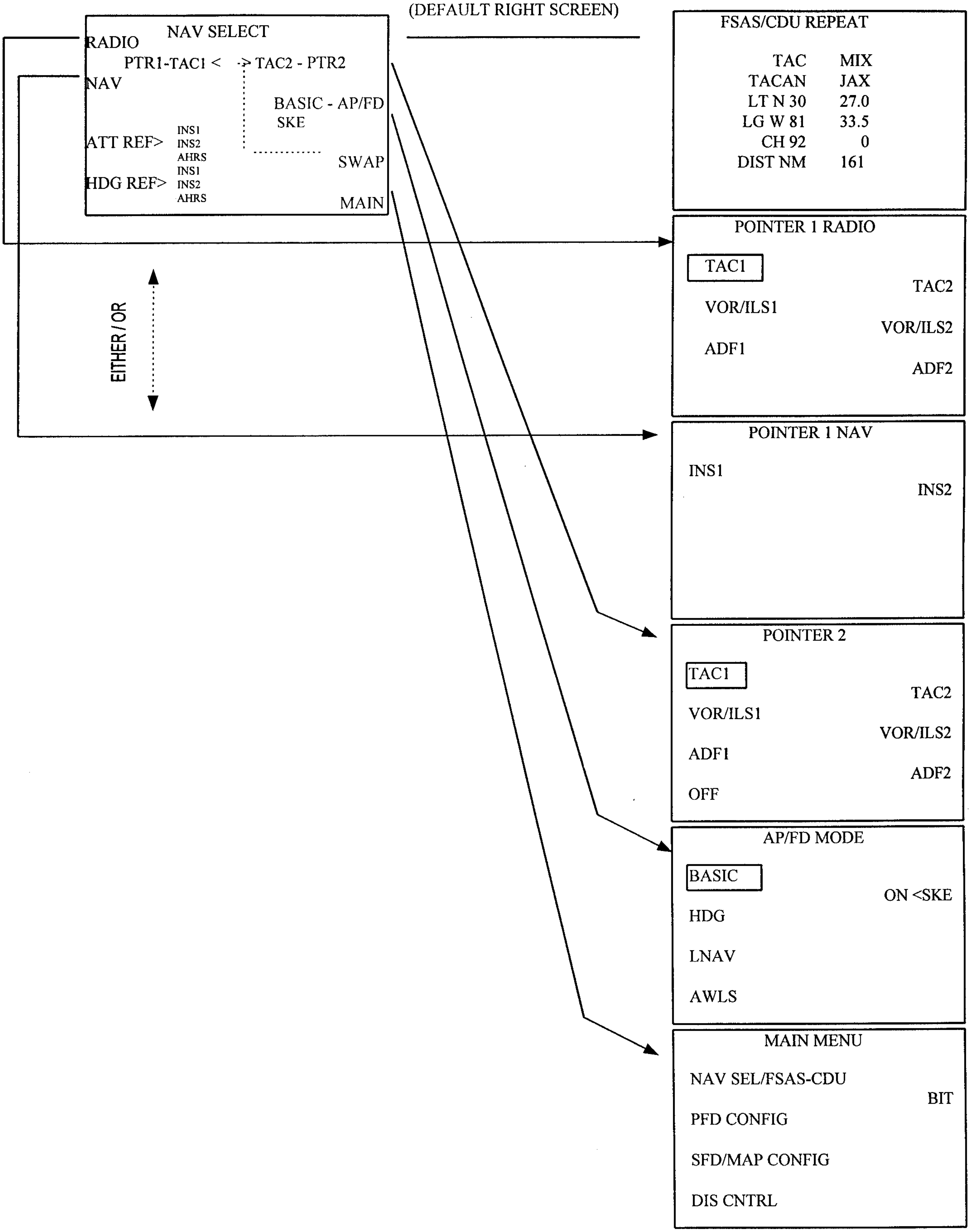


FIGURE 1. NAV SELECT MENU HIERARCHY - FIP FORMAT

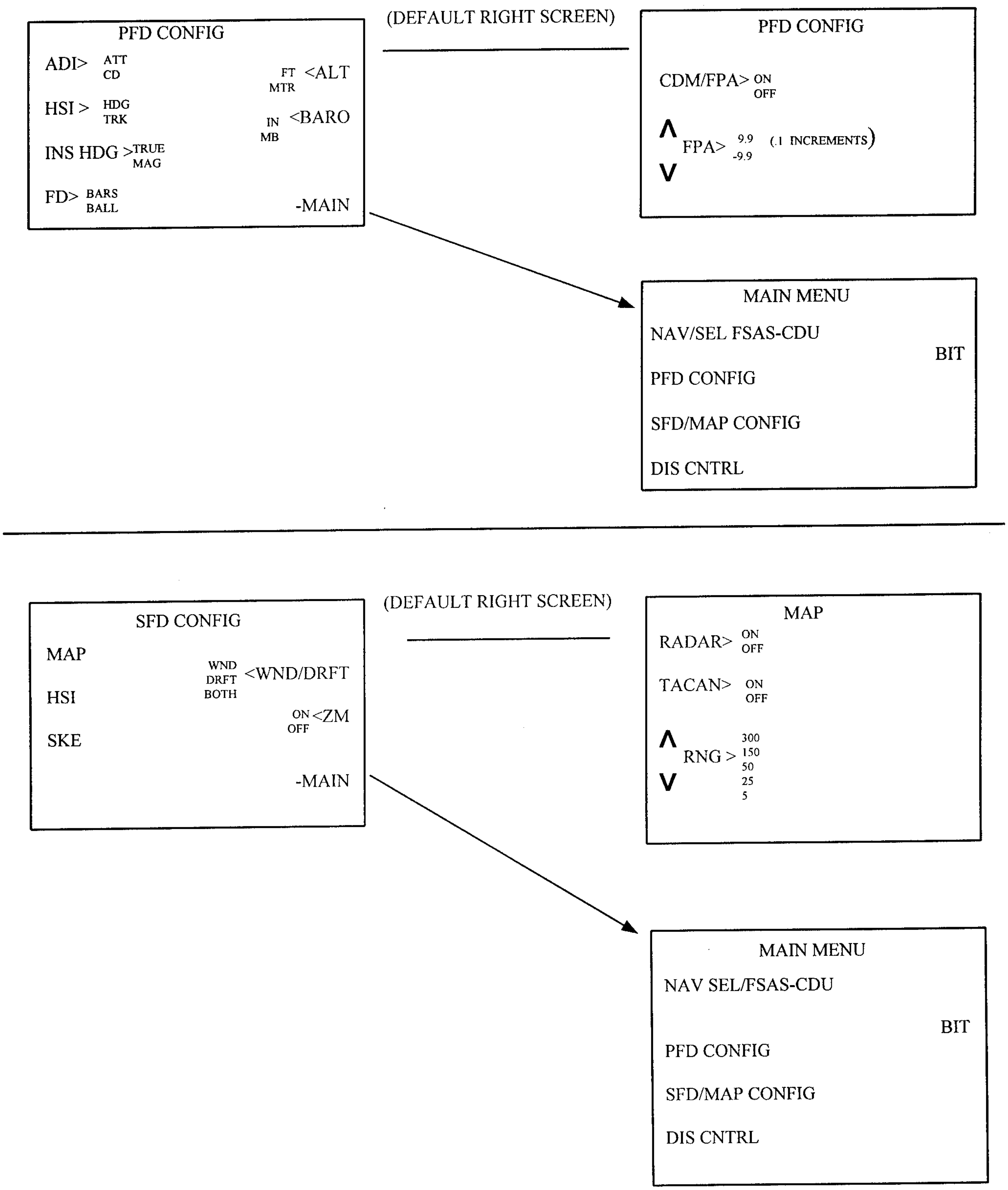


FIGURE 2. PFD/SFD CONFIG MENU HIERARCHY - FIP FORMAT

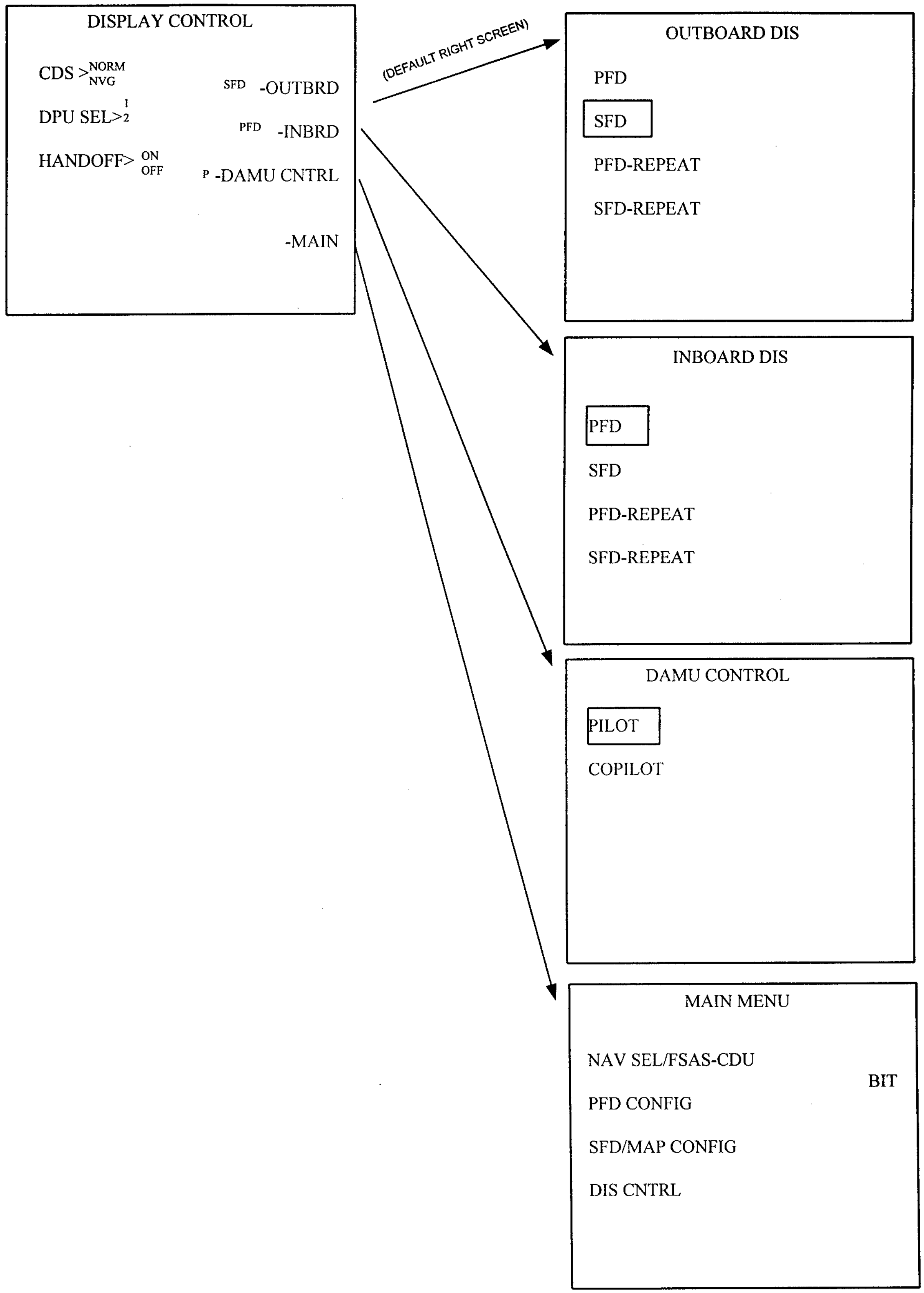


FIGURE 3. DISPLAY MENU HIERARCHY - FIP FORMAT

APPENDIX F

DAMU Script and Tasks

DAMU MISSION SCRIPT AND INDEPENDENT TASK TRIALS

SUBJECT INSTRUCTIONS:

You are about to complete a series of task trials that have been projected into various C-141 scenarios. You will NOT be flying the simulator for these tasks.

For each task, you will be verbally given explicit instructions similar to those of the pre-test. Please complete each task as quickly as possible without making any errors. Should you make an error, take the necessary steps to correct it. Accuracy is more important than speed.

Before each trial, place your right hand on the throttle. This is the starting position. The DAMU screens will be blank prior to each task trial and will appear at the being of each trial. Make all keypresses to the DAMU with your right hand. When each trial is completed, press the center key between the two DAMU screens. This action blank the DAMU screens for the next trial.

If you do not understand the nature of the task, please let me know immediately before starting the trial. I can not, however, explain to you how to complete the task.

[PRE -FLIGHT SET-UP]

The first series of tasks will involve configuring the avionics prior to flight.

You have arrived at the aircraft only to find that maintenance has been trouble shooting the displays. The maintenance supervisor has signed off the forms and you can now prepare the aircraft for departure.

The first menu you will see is the display control menu. It indicates that all default parameters have been changed. I will give you tasks that configure the displays for a standard instrument departure from McGuire AFB. You do not need to change your course or heading.

Are you ready? This first task is

TRIAL	SCRIPT
1	Change the ADI to attitude mode.
2	Make the altimeter show altitude in feet, and accept QNH in inches of mercury.
3	Put the HSI in heading-up mode. Make it also display magnetic heading.
4	Turn off the Climb-Dive Marker.
5	Make the Secondary Flight Display show map information.
6	Display both WIND direction and DRIFT angle on the MAP.
7	Turn the Zone Marker off.
8	Display TACAN stations and weather RADAR information.

9 Set the MAP range to 300 nautical miles.

PRE-DEPARTURE

The next series of tasks configure the navigation systems for a Point Pleasant 3, Runway 23, Standard Instrument Departure.

10 Select INS1 for attitude reference source.

11 Select INS1 for heading reference source.

12 You want to fly the 229 radial out to 6 DME. Change Bearing Pointer 1 to TACAN1 which is the McGuire VORTAC.

13 The next navaid on the SID is Coyle. Change Bearing Pointer 2 to VOR1.

14 Make the flight director show course steering cues.

15 Bring up the FSAS-CDU REPEAT screen so that you can see emergency return information.

GXU 229 at 6 DME

You are airborne and climbing out on the McGuire Vortac (GXU 229) at 6 DME.

16 Make the COYLE VORTAC, which is Bearing Pointer 2, the primary navigational aid.

MANTA

The following series of tasks are done over MANTA where you are about to transition to the high altitude structure. The aircraft is flying a heading of 056 degree on the HAMPTON 236 radial, 83 DME.

Remember to complete each task as quickly as possible without making any errors.

17 Make Bearing Pointer 1 display INS1 information.

18 TACAN 2 is tuned to Hampton, monitor its position by assigning it to Bearing Pointer 2.

AVOIDANCE VECTOR

Air Traffic Controller vectors you off the SID to avoid another aircraft. You have set the assigned heading into the Heading Marker.

19 Set the flight director to command a turn to the ATC assigned heading (AP/FD in HDG mode).

20 Set the MAP range to 150 nautical miles.

INS FAILURE

As you begin to coast out, the ADI rotates to an awkward attitude. Annuciations on the center console indicate that INS1, which you have been using for instrument flight and navigation, no longers works. The following series of tasks involve correcting for the INS failure.

21 Select AHRS as your attitude source.

22 Select AHRS as your heading source.

23 Navigate off INS2.

SKE FORMATION FLIGHT

You are at cruise on your way to the drop zone, transitioning from VFR conditions to IMC. The navigator has turned on Station Keeping Equipment and put it into transmit mode. The following tasks involve SKE formation flight.

24 Display the Station Keeping information on the PFD (Turn SKE ON in the AP/FD mode)

25 Make the Secondary Flight Display show station keeping azimuth range information. Turn the Zone Marker on.

LOCAL PROFICIENCY SORTIE

Now you are the instructor on a local training mission. You have been monitoring the co-pilot's progress on an instrument approach by repeating his inboard and outboard displays on your respective displays. Now that touch and go is complete, gear and flaps retracted, configure your displays for the VFR pattern.

26 Make the inboard display show your primary flight display information.

27 Make the outboard display show your secondary flight display information.

28 Put the ADI into Climb-Dive (flight path) Mode.

29 Set the Flight Path Angle to minus 3 point zero degrees.

INDEPENDENT TRIALS

The following tasks are independent of each other and will not be embedded in a mission context.

Remember to complete each task as quickly as possible without making any errors.

30	Change both Attitude and Heading Reference sources to INS2 and then to AHRS.
31	Command Processor Unit 2 to drive your primary and secondary flight displays.
32	Display expanded HSI and drift angle on the Secondary Flight Display.
33	Change the flight director steering cue from BARS to BALL
34	Select INS2 for attitude reference source.
35	Change to BASIC autopilot mode and then activate the station keeping equipment.
36	Select INS1 for heading reference source.
37	Change display systems from night vision goggles mode to NORMAL mode.
38	Change both Attitude and Heading reference sources to INS1 and then back to INS2.
39	Change auto-pilot flight director mode to AWLS.
40	Display station keeping information on the PFD and station keeping azimuth range information on the Secondary Flight Display.
41	Remove station keeping equipment information from the PFD.
42	Swap Bearing Pointer 1and Bearing Pointer 2 source information.
43	Make the outboard display repeat the copilot's Secondary Flight Display.
44	Change Bearing Pointer 1 to VOR1 and turn Bearing Pointer 2 off.
45	Enable the copilot to have control of your DAMU.
46	Take control of the copilot's DAMU.
47	Make the co-pilot's HSI display heading-up information.
48	You currently control the copilot's DAMUs. Take control of your own DAMU.

TRIAL NO.	PRE-TEST TASK TRIALS DESIGN A	TASK TYPE
1	Change to **Flight Path mode.**	PFD
2	Select **METERS** for **altitude** scale.	PFD
3	Display **DRIFT** angle on the MAP.	SFD
4	Show **MAP** range at **5 nm.**	SFD
5	Select **INS2** for **ATTitude** source from the NAV SEL page.	NAV-REF
6	Change **Bearing Pointer 1** to**VOR1** from NAV SEL page.	NAV-BP
7	Change **Bearing Pointer 2** to **VOR**2 from NAV SEL page.	NAV-BP
8	Bring up the **FSAS CDU repeat screen.**	NAV-AP
9	SWAP Bearing Pointer 1 and Bearing Pointer 2 Navigation information **(PTR1 to VOR2 / PTR2 to VOR1).**	NAV-BP
10	Display **SKE** positional information on the **SFD.**	SFD
11	Change **HDG** reference source to **AHRS** from the STATUS page.	NAV-REF
12	Display **MAP** on the **SFD**.	SFD
13	Make your **outboard** display repeat the Copilot's SFD (**SFD-R**).	DIS-CNTL
14	Set the **Flight Path Angle** to **-3.00.**	PFD
15	Change **ATTitude SOURCE** to **AHRS** from the STATUS page.	NAV-REF
16	Change **AP/FD** mode to **AWLS** from the STATUS page.	NAV-AP
17	Select **INS 2 for HDG reference source** from the STATUS page	NAV-REF
18	Change to **processor unit 2** for displays.	DIS-CNTL
19	Change **AP/FD** mode to **BASIC** and display SKE flight director information on the PFD. Do this from the NAV SEL page.	NAV-AP
20	Change **Bearing Pointer 1** to **INS1** from the NAV SEL page.	NAV-BP
21	Change the **HSI** to **TRACK-UP** mode.	PFD
22	**Repeat** co-pilot's **PFD** on your **outboard** display.	DIS CNTRL
23	Access the **copilot's** DAMU displays and controls.	DIS CNTL
24	Change **AP/FD mode** to **Lateral Navigation** from the STATUS page.	NAV-AP

TRIAL NO.	PRE-TEST TASK TRIALS DESIGN B	TASK TYPE
1	Change to **Climb-Dive Mode.**	PFD
2	Select **METERS** for **altitude** scale.	PFD
3	Display **DRIFT** angle on the MAP.	SFD
4	Show **MAP** range at **5 nm.**	SFD
5	Select **INS2** for **ATTitude** source.	NAV-REF
6	Change **Bearing Pointer 1** to**VOR1.**	NAV-BP
7	Change **Bearing Pointer 2** to **VOR**2.	NAV-BP
8	Bring up the **FSAS CDU repeat screen.**	NAV-AP
9	SWAP Bearing Pointer 1 and Bearing Pointer 2 Navigation information (**PTR1 to VOR2 / PTR2 to VOR1).**	NAV-BP
10	Display **SKE** positional information on the **SFD.**	SFD
11	Change **HDG** reference source to **AHRS.**	NAV-REF
12	Display **MAP** on the **SFD.**	SFD
13	Make your **outboard** display repeat the Copilot's SFD (**SFD-R**).	DIS-CNTL
14	Set the **Flight Path Angle** to **-3.00.**	PFD
15	Change **ATTitude SOURCE** to **AHRS.**	NAV-REF
16	Change **AP/FD** mode to **AWLS.**	NAV-AP
17	Select **INS 2 for HDG reference source.**	NAV-REF
18	Change to **processor unit 2** for displays.	DIS-CNTL
19	Change **AP/FD** mode to **BASIC** and display SKE flight director information on the PFD.	NAV-AP
20	Change **Bearing Pointer 1** to **INS1.**	NAV-BP
21	Change the **HSI** to **TRACK-UP** mode.	PFD
22	**Repeat** co-pilot's **PFD** on your **outboard** display.	DIS CNTRL
23	Access the **copilot's** DAMU displays and controls.	DIS CNTL
24	Change **AP/FD mode** to **Lateral Navigation.**	NAV-AP

APPENDIX G

DAMU Evaluation Questionnaires and SWORD Forms

C-141 Display Avionics Management Unit (DAMU) Questionnaire

Instructions: The following questions ask you to evaluate the DAMU menu system. Base your responses on hands-on experience, tasks you have performed during part-task testing as well as on your operational experience. For each question, please enter your rating in the space provided or check the desired answer, as appropriate. If the question requires a written response, please be as detailed as possible.

We also encourage you to write comments where space is provided. These comments are very important for the interpretation of data, and will aid us in diagnosing specific design deficiencies and identifying good design features. If you are unsure of any question, please ask the test engineer.

SUBJECT #:______

DESIGN: A B (circle one)

DAMU QUESTIONNAIRE Part 1

RATING SCALE (please use this rating scale for **Questions 1-10**):

- **a. Completely Acceptable:** Good design as is.
- **b. Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- **c. Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- **d. Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- **e. Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

1. The understandability and clarity of the menu page titles are: _________

   Comments:

2. Overall, the readibility of the text on the DAMU is: __________

   Comments:

3. The understandability and ease of use of symbol conventions are: __________

   Comments:

4. The overall operational utility of the DAMU Menu System is: ___________

   Comments:

5. Overall, the understandability and ease of use of the pages/options in the NAV SELECT Menu are:__________

   If answered **c - e**, which page(s) or option(s) did you have trouble with?

6. Overall, the understandability and ease of use of pages/options in the SFD and MAP Menus are:__________

   If anwered **c - e**, which page(s) or option(s) did you have trouble with?

SUBJECT #: ______

DESIGN: A B (circle one)

7. Overall. the understandability and ease of use of the options in the PFD Menu are: ___________

   If answered **c - e**, which option(s) did you have trouble with?

8. Overall, the understandability and ease of use of the pages/options in the DISPLAY CONTROL Menu are:_________

   If answered **c - e**, which page(s) or option(s) did you have trouble with?

9. The ease of accessing the other crew member's DAMU displays and controls in the DISPLAY CONTROL Menu is: __________

   Comments:

10. The ease of interpreting and implementing SKE related-options (putting SKE information into the flight director and displaying on the PFD, repeating SKE information on the SFD, turning Zone Marker on) is: ________

    Comments:

11. The DAMU menus facilitate safe flight operations.

    a. ____ Strongly agree
    b. ____ Moderately agree
    c. ____ No opinion
    d. ____ Moderately disagree
    e.. ____ Strongly disagree

    If answered **d** or **e**, please comment:

12. Is any unnecessary information displayed that could be deselectable to reduce clutter?

    ____ Yes
    ____ No

    If **YES**, please comment:

SUBJECT #:_____

DESIGN: A B (circle one)

13. Did you "get lost" navigating through the menu system?
    a. ____Always
    b. ____Usually
    c. ____Sometimes
    d. ____Never

    If answered **a, b,** or **c,** please describe which menu pages were difficult to access and the task.

14. Are options where you expected them to be in the menu structure?

    a. ____Always
    b. ____Usually
    c. ____Sometimes
    d. ____Never

    Comments:

15. Does the design degrade your ability to perform your tasks?

    ____Yes
    ____ No

    If **YES**, please elaborate.

16 Did you understand the functions being accomplished by the different menu options?

    a. ____Always
    b. ____Usually
    c. ____Sometimes
    d. ____Never

    Comments:

SUBJECT #:_____

DESIGN: A B (circle one)

17. Please recommend any improvements to the current menu design that you feel would improve efficiency and reduce workload.

SUBJECT #:______

DAMU GENERAL QUESTIONNAIRE - Part 2

(To be completed after <u>both</u> Design A and Design B testing sessions are finished)

1. Ease of Use:

    ______ **Strongly preferred <u>Design A</u>**
    ______ **Moderately preferred <u>Design A</u>**
    ______ **Did not prefer one design over the other**
    ______ **Moderately preferred <u>Design B</u>**
    ______ **Strongly preferred <u>Design B</u>**

2. Correlation with current C141 operations (check one):

    ______ **Strongly preferred <u>Design A</u>**
    ______ **Moderately preferred <u>Design A</u>**
    ______ **Did not prefer one design over the other**
    ______ **Moderately preferred <u>Design B</u>**
    ______ **Strongly preferred <u>Design B</u>**

3. What design features did you like about Design A?

4. What design features would you change on Design A?

5. What design features did you like about Design B?

6. What design features would you change on Design B?

SUBJECT #: _____

RATING SCALE (please use this rating scale for following 4 questions):

a. Completely Acceptable: Good design as is.
b. Moderately Acceptable: Minor design deficiencies that do not impact pilot performance.
c. Borderline: Design deficiencies that could impact pilot performance; changes desirable.
d. Moderately Unacceptable: Design deficiencies that will degrade pilot performance; corrections required.
e. Completely Unacceptable: Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

7. The utility of the SWAP key for current C-141 operations is: _________

Comments:

8. The utility of selecting a particular display processor unit is:_________

Comments:

9. The DAMU's glare shield location is: _________

Comments:

10. The utility of repeating the FSAS/CDU on the DAMU screen is: _________

Comments:

11. Currently some DAMU menu options are displayed but can not be selected (for example, when using INS as your primary NAVAID, you can see and select HDG UP/TRK UP and TRUE/SYN MAG modes...However, when in TACAN, you can see but <u>not</u> select these options.

Would this be confusing in an operational environment?

If so, what should be done differently?

SWORD QUESTIONNAIRE INSTRUCTIONS

The SWORD technique assesses workload by utilizing a series of pairwise comparisons between various system configurations. For this study, system configurations consist of combinations of three display designs and three task types. The display designs are: 1) DAMU Design A, 2) DAMU Design B, and 3) Current C-141 Design. The tasks are: 1) Selection of a primary Bearing Pointer NAV source (use of the NAV SELECT page or panel), 2) Selection of a Flight Director mode (use of the NAV SELECT page or Autopilot Panel) and 3) Selection of an attitude and/or heading reference source (use of the NAV SELECT page/panel).

Making comparison judgments for some design/task configurations may seem unnatural. However, it is imperative for analysis purposes, that you rate to the best of your ability the design/task configuration that you <u>think</u> will cause higher workload. Base your responses on hands-on experience, tasks you have performed during part-task testing, and operational experience.

The following examples compare workload between one or two task types: 1) assigning a navigational source to a primary bearing pointer (**NAV**) and 2) selecting a flight director mode (**FD**) combined with one of three DAMU designs: Design A, Design B and C-141 design.

Example 1- shows that the NAV task causes *substantially more workload* than the FD task utilizing Design A.

>>>> >>> >> > EQUAL < << <<< <<<<

Design A-NAV X ___ ___ ___ ___ ___ ___ ___ ___ | ___ | ___ ___ ___ ___ ___ ___ ___ ___ Design A - FD

Example 2 - shows that the NAV task causes *moderately more workload* for Design A than for Design B.

>>>> >>> >> > EQUAL < << <<< <<<<

Design A-NAV ___ ___ ___ X ___ ___ ___ ___ | ___ | ___ ___ ___ ___ ___ ___ ___ ___ Design B - NAV

Example 3- shows that the NAV task utilizing Design A causes s*lightly more workload* than the FD task utilizing the current C -141 design.

>>>> >>> >> > EQUAL < << <<< <<<<

Design A-NAV ___ ___ ___ ___ ___ ___ ___ X ___ | ___ | ___ ___ ___ ___ ___ ___ ___ ___ Design C141- FD

Example 4- shows that the NAV task utilizing Design A and the FD task utilizing Design B causes an *equal* amount of workload.

>>>> >>> >> > EQUAL < << <<< <<<<

Design A-NAV ___ ___ ___ ___ ___ ___ ___ ___ | X | ___ ___ ___ ___ ___ ___ ___ ___ Design B - FD

SUBJECT # ______

Which display/task configuration elicits more workload?

	>>>>	>>>	>>	>	EQUAL	<	<<	<<<	<<<<	
Design A - NAV										Design A - FD
Design A - NAV										Design A - ATT/HDG
Design A - NAV										Design B - NAV
Design A - NAV										Design B - FD
Design A - NAV										Design B - ATT/HDG
Design A - NAV										C141 Design - NAV
Design A - NAV										C141 Design - FD
Design A - NAV										C141 Design - ATT/HDG
Design A - FD										Design A - ATT/HDG
Design A - FD										Design B - NAV
Design A - FD										Design B - FD
Design A - FD										Design B - ATT/HDG
Design A - FD										C141 Design - NAV
Design A - FD										C141 Design - FD
Design A - FD										C141 Design - ATT/HDG

CONTROL / DISPLAY INTERFACE:
Design A
Design B
Current C141 Design

TASKS:
NAV = Assign Nav Source to Primary Bearing Pointer
FD = Select Flight Director Mode
ATT/HDG = Select ATT or HDG Reference Source

SUBJECT # ______

Which display/task configuration elicits more workload?

	>>>>		>>>		>>		>		EQUAL		<		<<		<<<		<<<<	
Design A - ATT/HDG																		Design B - NAV
Design A - ATT/HDG																		Design B - FD
Design A - ATT/HDG																		Design B - ATT/HDG
Design A - ATT/HDG																		C141 Design - NAV
Design A - ATT/HDG																		C141 Design - FD
Design A - ATT/HDG																		C141 Design - ATT/HDG
Design B - NAV																		Design B - FD
Design B - NAV																		Design B - ATT/HDG
Design B - NAV																		C141 Design - NAV
Design B - NAV																		C141 Design - FD
Design B - NAV																		C141 Design - ATT/HDG
Design B- FD																		Design B - ATT/HDG
Design B- FD																		C141 Design - NAV
Design B- FD																		C141 Design - FD
Design B- FD																		C141 Design - ATT/HDG

CONTROL / DISPLAY INTERFACE:
Design A
Design B
Current C141 Design

TASKS:
NAV = Assign Nav Source to Primary Bearing Pointer
FD = Select Flight Director Mode
ATT/HDG = Select ATT or HDG Reference Source

SUBJECT # ______

Which display/task configuration elicits more workload?

	>>>>		>>>		>>		>		EQUAL		<		<<		<<<		<<<<	
Design B - ATT/HDG	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - NAV
Design B - ATT/HDG	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - FD
Design B - ATT/HDG	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - ATT/HDG
C141 Design - NAV	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - FD
C141 Design - NAV	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - ATT/HDG
C141 Design - FD	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	___	C141 Design - ATT/HDG

CONTROL / DISPLAY INTERFACE:
Design A
Design B
Current C141 Design

TASKS:
NAV = Assign Nav Source to Primary Bearing Pointer
FD = Select Flight Director Mode
ATT/HDG = Select ATT or HDG Reference Source

APPENDIX H

Ratings and Responses from the DAMU Questionnaires

DAMU FORMAT										
	FREQUENCY Design A (FIP)					FREQUENCY Design B (CONOP)				
1. DAMU Questionnaire - Part 1	**5**	**4**	**3**	**2**	**1**	**5**	**4**	**3**	**2**	**1**
A. The understandability and clarity of the menu page titles are:	8	3	1	0	0	8	4	0	0	0
B. Overall, the readiability of the text on the DAMU is:	11	1	0	0	0	9	3	0	0	0
C. The understandability and ease of use of symbol conventions are:	10	1	0	0	0	12	0	0	0	0
D. The overall operational utility of the DAMU Menu System is:	7	2	3	0	0	8	4	0	0	0
E. Overall, the understandability and of use of the pages/options in the NAV SELECT Menu are:	7	2	3	0	0	5	7	0	0	0
F. Overall, the understandibility and ease of use of pages / options in the SFD and MAP Menus are:	9	2	1	0	0	9	3	0	0	0
G. Overall, the understandability and ease of use of the options in the PFD Menu are:	5	7	0	0	0	8	3	0	0	0
H. Overall, the understandability and ease of use of the pages / options in the DISPLAY CONTROL Menu are:	6	4	2	0	0	8	2	1	0	0
I. The ease of accessing the other srew member's DAMU displays and controls in the DISPLAY CONTROL Menu is:	9	2	1	0	0	9	2	1	0	0
J. The ease of interpreting and implementing SKE related-options (putting SKE information into the flight director and displaying on the PFD, repeating SKE information on the SFD, turning Zone Marker on is:	4	4	4	0	0	7	3	1	0	0
K. The DAMU menus facilitate safe flight operations:	4	4	2	2	0	5	5	0	1	0

				Y	**N**				**Y**	**N**
L. Is any unnecessary information displayed that could be deselectable to reduce clutter?				2	10				1	

		4	**3**	**2**	**1**		**4**	**3**	**2**	**1**
M. Did you "get lost" navigating through the menu system?		0	0	9	3		0	0	9	3
N. Are options where you expected them to be in the menu structure?		3	8	1	0		1	11	0	0

				Y	**N**				**Y**	**N**
O. Does the design degrade your ability to perform your tasks?				3	9				2	10
P. Are options for toggle selections apparent?**										
Q. Did you understand the functions being accomplished by the different menu options?				9	3				11	1

DAMU FORMAT					
	FREQUENCY				
2. DAMU Questionnaire - Part 2	**Strongly Prerferred Des sign A**	**Moderately Perferred Design A**	**No Preference**	**Moderately Preferred Design B**	**Strongly Preferred Design A**
A. :Ease of Use	0	3	1	5	3
B. Correlaton with Current C-141 Operations	1	2	1	5	3

	5	4	3	2	1
C. Utililty of the SWAP key	10	1	1	0	0
D. Utility of sleecton rocesor unit for displays	10	1	0	0	0
E. Damu glareshield location	8	1	1	0	0
F. Utility of repeating FSAS/CDU	11	0	0	0	0

DAMU CONFIGURATION: Open-Ended Question Responses & Comments

Part 1:

1. Is any unnecessary information displayed that could be deselectable to reduce clutter? If YES, please comment:

DESIGN A

Subject 7: Several menus could be combined or eliminated w/a more logical hierarchy, e.g. handoff enabled disabled DAMU P CP (See picture)

DESIGN B

Subject 5: Not that I can see

Subject 9: Why not have a page for "SKE" options in just one place, and a similar page for CAT II or whatever else?

Subject 7: Does the design degrade your ability to perform your tasks? If **YES**, please elaborate.

DESIGN A

Subject 7: Somewhat, either I have to toggle through menus to find the right screen or guess.

DESIGN B

Subject 1: having ATT/HDG selections readily available is a plus.

Subject 7: Initially, but through use and training this will decrease over time.

Subject 8: Just slightly. Since all the options are not readily visible such as rows of labeled buttons, it takes just a little longer to find the menu page and select the desired function. It is probably not feasible to have rows of labeled buttons considering all the different combinations.

17. Please recommend any improvements to the current menu design that you feel would improve efficiency and reduce workload. (THIS WAS QUESTION 18 FOR SUBJECTS 2-8)

DESIGN A

Subject 1: Place labels on the PFD's and SFD's so I know at a glance what I have displayed (i.e.. Pilots or #1 PFD copilots or #2 PFD)

Subject 5: Items already mentioned: - Name conventions for PFD & SFD change to inboard and outboard in display control.. -SYN Mag- not clear, Do I select synthetic magnetic or rear magnetic or is it between TRVE and MAG?

Subject 6: It would be nice to be able to engage altitude, Hold from DAMU along with Basic auto pilot. This could be very helpful in a task saturated environment. If you are going to make DAMU so flexible (good Option) please include a "DAMU-checked (CP, P)" as part of Before Takeoff, approach and Descent checks. When a pilot has control of CP DAMU please have (CP) reverse video and flashing on top of menu pages. FSAS CDU repeat -NICE OPTION!

Subject 7: Change the approach to the info to be displayed. EG. have the main select what is to be changed, vs. NAV, PFD, SFD, DISPLAY CONTR. TO (SEE PICTURE)

Subject 9: Lose a couple of pages like SFD-WIND could be a toggle. Eliminating the need to erase a screen. I found myself wondering what I lost when a screen changed. Perhaps an addition of a recall option like the one on the FSAS.

Subject 10: Excellent format- logical and easy to use.

DESIGN B

Subject 2: Since your are changing the primary radios for navigation why not have the NAV SELECT as the main/primary page, or put a selectable time limit in which after other functions are completed it automatically comes back to the NAV SELECT page.

Subject 4: A very workable system. A good confidence builder. May require extensive training of pilots to operate.

Subject 5: (This is question 17 for Subject 5) I prefer the B design over the A. Because of Reduced number of pages, toggling for choices, complete grouping of related items on each page. These things reduced the amount of hunting around and it was clear enough to find you way back to correct (place?)

Subject 9: When swapping from course arrow #1 to # 2, the course doesn't move. It would be nice to preset a crossing radial or course to ve intercepted so that a "swap" button would be more useful.

Subject 10: In my opinion, it really doesn't matter what the menus are, as long as they make sense and never change. Regardless of how you arrange the selection, people will be debating the merits of this vs. that till time ends. Several times, I have lost the screen on the FSAS and had to pull up modes from memory. Fortunately this is no big deal because the menus never change- after initial training, we rarely ever read the menus anyway. We know what button we are going to push before we pull up the screen. As long as the DAMU is simple, logical and consistant it will get the job done. We will memorize whatever you give us (We have no choice). The limitus test is to cover the screens and still be avle to complete all desired tasks. From there, the only refinement required is that which would reduce keystrokes.

18. Please recommend any improvements to the current menu design that you feel would improve efficiency and reduce workload.

Subject 1: Label the PFD/SFD "Pilot" and Copilot"